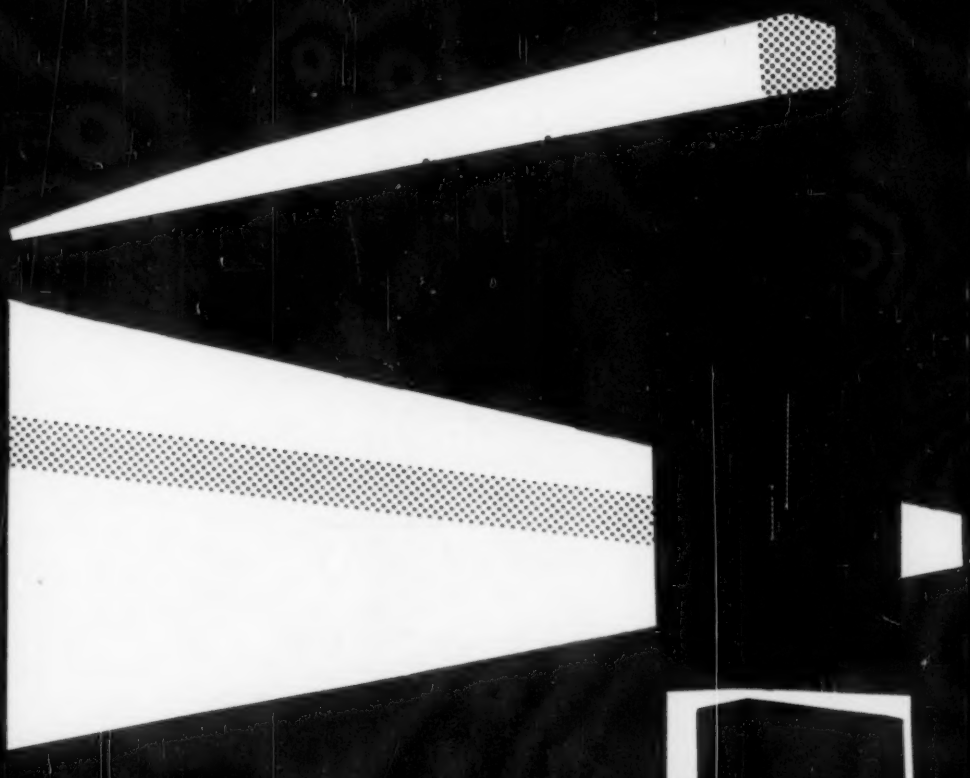
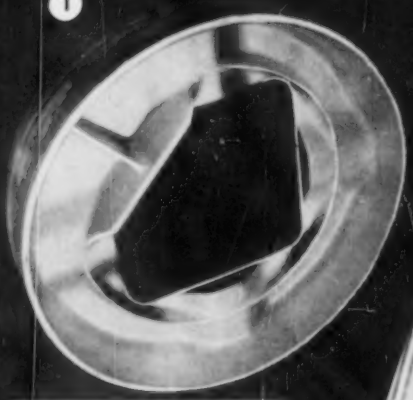
JOURNAL OF

METALS

JANUARY 1958



HIGH FLYING FORGINGS



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JOURNAL OF

METALS

VOL. 10, NO. 1 JANUARY 1958

Published to provide a continuing, authoritative, and up-to-date record of technological, engineering, and economic progress in all branches of the industry by The Metallurgical Society, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 29 West 39th Street, New York 18, N. Y.

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Always distinctive is the aluminum plant design . . . interpreted by cover artist Naomi Lazard. Within the cover are to be found four articles on aluminum . . . economics of reduction cells, plastic refractories, the French aluminum industry, and aluminum's application to electrical engineering. Also included are articles on magnesium and titanium.

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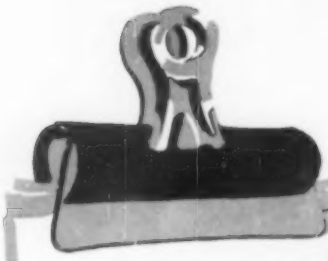
Published the first day of each month by the American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., 29 West 39th Street, New York 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $8 per year for non-AIME members in United States and North, South, and Central America; $10, foreign; $6 for AIME members, or $4 additional for members only in combination with a subscription to "Mining Engineering" or "Journal of Petroleum Technology." Single copies, 75 cents; single copies foreign, $1.00; special issues, $1.50 . . . The AIME is not responsible for any statement made or opinion expressed in its publications . . . Copyright 1958 by the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. . . . Registered cable address, AIME New York . . . Indexed in Engineering Index, Industrial Arts Index, and Chemical Abstracts . . . Second class mail privileges authorized at New York, N. Y., and additional entry established at Manchester, N. H. Number of copies in this issue 10,600.



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From the Desk of the President

To: Purchasing Department

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Sales Engineer, B.S. in metallurgy or metallurgical engineering, with five to ten years experience in metallurgical field with minimum of three years in sales on heat resistant alloy castings. Some understanding of corrosion and abrasion problems desirable. Salary, $9600 a year. Territory: area covering Indiana, parts of Michigan, Chicago, and surrounding territory. W5624.

Metallurgist, with two to five years experience covering chemical, metallurgical, and radiographic testing of stainless steel castings, forgings, and corrosion-resistant materials. Salary, $6500 to $8000 a year. Location, Newark, N. J., area. W5621.

Senior Design Engineer, mechanical or metallurgical engineering graduate, with at least ten years design and layout of metallurgical products plants including powder metallurgy installations. Salary, $10,000 to $12,000 a year. Location, New York. W5606.

Metallurgists. a) *Senior Metallurgist,* 35 to 45, with graduate degree in metallurgy and minimum of ten years operating and research experience in nonferrous minerals beneficiation; to have line control of principal ore dressing laboratory and pilot plant and functional control over metallurgy at operating concentrators. Duties will include plant studies, economic evaluations, and flowsheet design recommendations for new plants and additions. b) *Plant Metallurgist,* 30 to 40, with degree in metallurgy, metallurgical engineering, or ore dressing and a minimum of five years experience in base metal sulfide plants and laboratory work. Under line control of principal plant superintendent and functional control of senior metallurgist. Will conduct laboratory studies and be responsible for application of improvements to plant circuits. Salaries commensurate with experience; housing available; 33-month contract, transportation, and other benefits. Location, South America. F5592.

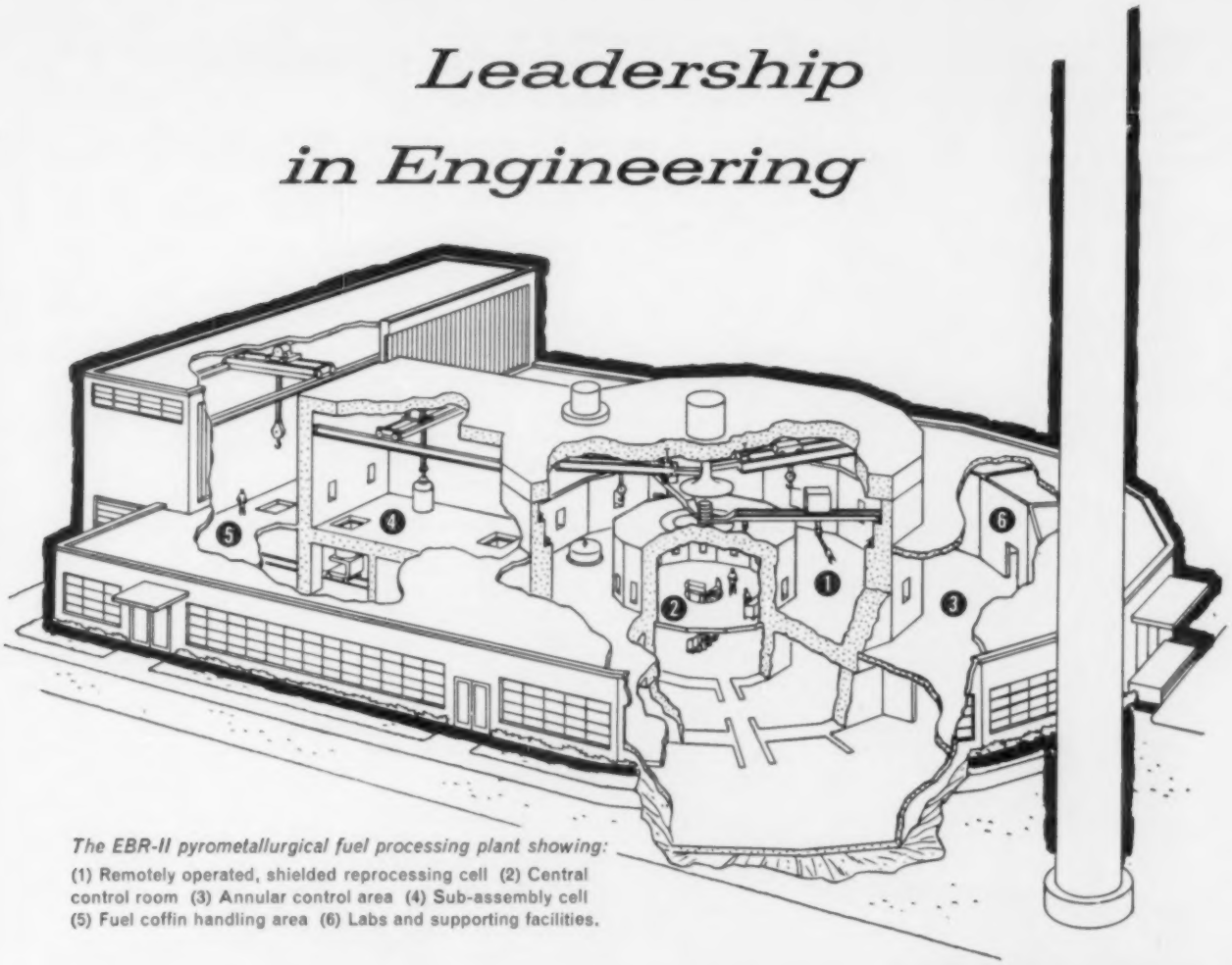
Research Metallurgical Engineers, B.S. or M.S. degree, with two to five years experience in one or more of the following fields: extraction metallurgy, powder metallurgy, fiber metallurgy, high temperature materials, ceramics, and ceramic-metal composites. Definite interest in research activities and ability to establish, supervise, and analyse projects with a minimum of supervision. Apply by letter giving details of education, work experience, and salary requirements. Location, Wisconsin. W5567-C.

Sales Engineer, chemical or metallurgical engineering graduate, with at least eight years process and equipment sales experience in chemical, metallurgical, or nuclear fields. Some traveling. Salary, $10,000 to $12,000 a year. Location, New York. W5380.

Metallurgical Engineers. a) *Metallurgical Engineer, Junior,* to 30, chemical or metallurgical engineering degree, with four to seven years experience in lead and/or zinc application technology desired; will consider production experience. Duties will include development of new markets and outlets for nonferrous products by finding new applications in the consuming industry; determine needs of consumers for new products, etc. Salary, $6000 to $9000 a year. b) *Metallurgical Engineer, Senior,* to 45, (#78b-

(Continued on page 4)

Leadership in Engineering



The EBR-II pyrometallurgical fuel processing plant showing:
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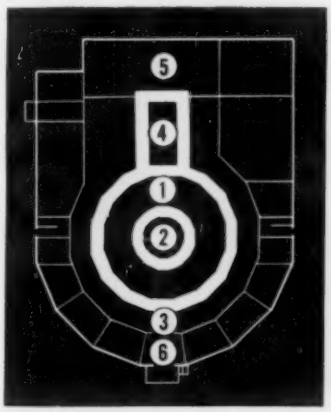

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Personnel

(Continued from page 2)

57), chemical or metallurgical engineering degree, with six to ten years experience in lead and/or zinc application technology; will consider production experience. Duties as above. Salary, $9,000 to $12,000 a year. Location, New York. W5327.

Physical Metallurgist excellent opportunity available for B.S. or M.S. with approximately five years experience. Duties will include studies of equipment failure and research on corrosion resistance and quality control. Will also supervise and correlate operations of testing laboratory. Salary, open. Location, Ohio. W5028.

BOOKS

Nucleonics, reprint of Vol. 10, 1952, is now available from the *Johnson Reprint Corp.*, 111 Fifth Ave., New York 3, N. Y., paper bound, $25.00 Vols. 1 to 10, 1947-1952, cloth bound set, $190.00. Previously reprinted are: Vols. 1 to 6, 1947-1951, paper bound, each $16.00. In preparation are: Vols. 11 to 13, 1953-1955, each approximately $25.00.

ASTM Standards on Copper and Copper Alloys, by the *American Soc. for Testing Materials*, 1916 Race St., Philadelphia, 3, Pa., 674 pp., $6.25, 1957.—A convenient compilation of the methods of test and specifications pertaining to copper and copper-alloy sheet, strip, bar, shapes, wire, pipe and tube, copper and copper-alloy electrical conductors, copper castings, and nonferrous metals used in copper alloys. Some 130 standards are included of which 34 have been revised since the last compilation in 1955. The standards are grouped in broadly classified sections with a subject index, and also a listing in numerical sequence. •

The Making, Shaping and Treating of Steel, 7th Edition, by *U. S. Steel Co.*, 525 William Penn Place, Pittsburgh 30, Pa., 1048 pp., $7.50, 1957.—The result of a cooperative of some 200 of the technical and research personnel of the U. S. Steel Co., this standard reference work has again been thoroughly revised and largely rewritten. The information contained is a compilation of past and present practices in the iron and steel industry, based on practical experience. In addition to the extensive coverage of the processes named in the title, the work covers fundamental chemical and physical principles, fuels and combustion, metallurgical coke production, recovery of coal chemicals, iron ores, refractories, fluxes and slags, sponge and wrought iron, special steels, and mechanical testing methods. A detailed 100-pp. index provides rapid reference to the text material.

Vacuum Melting, eight authors, *Vacuum Melting Report*, 1383 Panther Rd., Rydal, Pa., $7.50, 1957.—This publication was originally prepared as a report for Professor Georges Doriot's manufacturing course at the Harvard Business School. The book is the first comprehensive work on a technique that has grown from laboratory infancy to commercial importance in the last 20 years. History, the process, properties and uses of vacuum melted metals, and economics are covered in the work.

X-ray Crystal Structure, by Dan McLachlan Jr., Stanford Research Institute, *McGraw-Hill Book Co. Inc.*, 340 pp., $15.00, 1957.—This illustrated book gives a logical modern picture of the advanced phases of crystal structure analysis by X-ray methods; and at the same time supplies the reader with the work of the pioneers of crystallography in condensed form. The work tells how to determine the atomic positions with-

(Continued on page 6)

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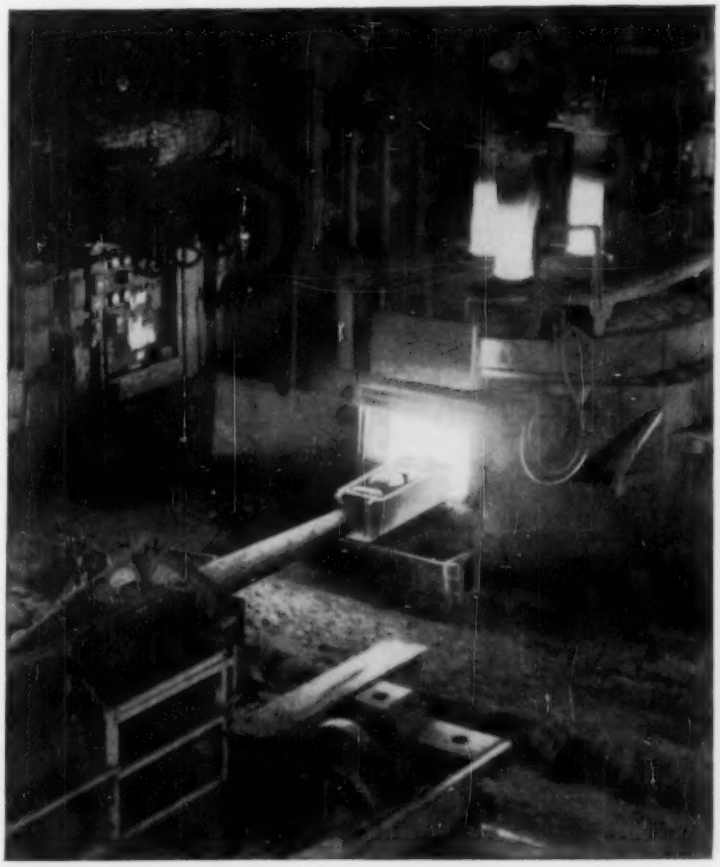

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Books

(Continued from page 4)

in a crystalline material, using the X-ray data obtained from single crystals. It stresses the theory of space groups, single crystal cameras, Fourier methods, the phase problem, computing devices, and the derivation of the point groups; and combines theoretical background with practical applications.

Atomic Radiation *RCA Service Co. Inc.*, Government Service Dept., Bldg. 210, Camden 8, N. J., 120 pp., $1.60 single copy, $1.45 each, ten copies or more, 1957.—*Atomic Radiation* discusses, in simplified terms, nuclear physics, observed biological effects of radiation, monitoring instruments, permissible radiation doses, and medical evaluation of injuries and treatments. Primarily designed for use by technicians and scientists engaged in nuclear power activities, it was originally prepared under contract for the U. S. Air Force, which has approved reprinting and commercial sale.

The Rolling of Strip, Sheet and Plate, by Eustace C. Larke, *The Macmillan Co.*, 404 pp., $12.75, 1957.—This book is specifically designed to meet the needs and stimulate the interests of rolling mill managers, their technical and practical assistants, engineers concerned with the design of plant and with its operation, and metallurgical and engineering students. The author deals at length with roll cambers, causes and control of gage variation, factors which affect the rolling load, the design of rolling schedules which ensure maximum production, the caculation of the roll separating forces developed during hot and cold rolling and how the associated energy consumed and the horse power developed can be computed. These and many other matters are discussed in detail and readers will welcome the inclusion of fully worked out numerical examples. •

1958 Arco Income Tax Guide, fourth issue, by S. Jay Lasser, *Arco Publishing Co.*, 480 Lexington Ave., New York 17, N. Y., 128 pp., $1.00, 1957.—This manual is prepared specifically for the filing of 1957 tax returns and takes the American taxpayer through his tax form step-by-step, and shows him how to make the greatest savings on every and any item. By dealing only with laws applicable to this year's taxes (due Apr. 15, 1958), and eliminating the kind of technical jargon which is useless and confusing to the taxpayer, the guide makes possible a relatively painless payment of taxes. Additional features include tax tips and record-keeping forms for 1958 returns; a complete list of important tax-saving possibilities; and sample filled-out forms for guidance and illustration.

Tentative Specifications for Copper and Copper-Alloy Arc-Welding Electrodes, (ASTM B 225-57 T; AWS A 5.6-57 T), just issued by the *American Welding Soc.*, 33 W. 39th St., New York 18, N. Y. and the *American Soc. for Testing Materials*, 1916 Race St., Philadelphia 3, Pa., 40¢, issued 1948, revised 1953, 1957, a reprint from copyrighted ASTM publications.—For the first time two types of stranded aluminum-bronze electrodes (ECuAl—A2 and ECuAl —B) are covered by a specification. In addition, one type of aluminum-bronze electrode (ECuAl—A2) for use with the submerged arc process is standardized. The eight classifications in this edition include copper, Cu-Si, Cu-Sb, Cu-Ni, and Cu-Al electrodes. Chemical composition, mechanical properties, and usability characteristics of each classification are given together with tests for verifying these properties. An appendix is included. •

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Special Report On Results of Renegotiation, by *The Renegotiation Letter* Evans Bldg., Washington 5, D. C., 116 pp., $10.00, 1957.—This new book reveals the detailed reasons why the Renegotiation Board ordered 49 defense contractors and subcontractors to refund $54 million of excessive profits. Ordinarily, results of renegotiation are kept confidential; the data in the book, however, became available when the 49 contractors appealed to the U. S. Tax Court, and in so doing disclosed negotiation results. Revealed along with the complete identity of each company are the financial operations, amount of profit by dollars and percent, and amount the companies that were allowed to retain on defense contracts. The highlight of the book is an individual report on 31 cases which includes the official summary of the facts and reasons of the Renegotiation Board for ordering refunds. Also disclosed is the status of each of the 49 cases, including all appeals filed in the Tax Court through Oct. 31, 1957, limited to cases involving the Renegotiation Acts of 1948 and 1951.

American Standard Definitions of Electrical Terms (C42), by the *American Institute of Electrical Engineers*, 29 W. 39 St., New York 18, N. Y.,—Nine volumes of the dictionary have just come off the press. Sixteen American Standards will make up the complete dictionary, with meanings of 10,000 terms, when published by the AIEE. The nine standards, newly printed, cover definitions for rotating machinery, switchgear, industrial control equipment, instruments, meters and meter testing, generation, transmission and distribution, electrochemistry and electrometallurgy, electron devices, electrobiology, including electrotherapeutics, and mining.

ASTM Viscosity Tables For Kinematic Viscosity Conversions and Viscosity Index Calculations, ASTM Special Technical Publication No. 43-B, by the *American Soc. For Testing Materials*, 1916 Race St., Philadelphia 3, Pa., 65 pp., $2.00, 1957.—With the adoption of 1.0038 cs at 68°F as the standard value for the kinematic viscosity of water on July 1, 1953, recalibration of viscometers used for measuring kinematic viscosity was required. The tables in this book provided a convenient means for viscosity conversions and for obtaining basic values for calculation of viscosity index. Useful to petroleum chemists, lubrication engineers, and production personnel, the tables include: conversion of kinematic viscosity to Saybolt furol viscosity, basic values for calculating viscosity index from Saybolt universal viscosity, and factors for converting kinematic viscosity to Saybolt universal viscosity at temperatures from −100 to +500°F. •

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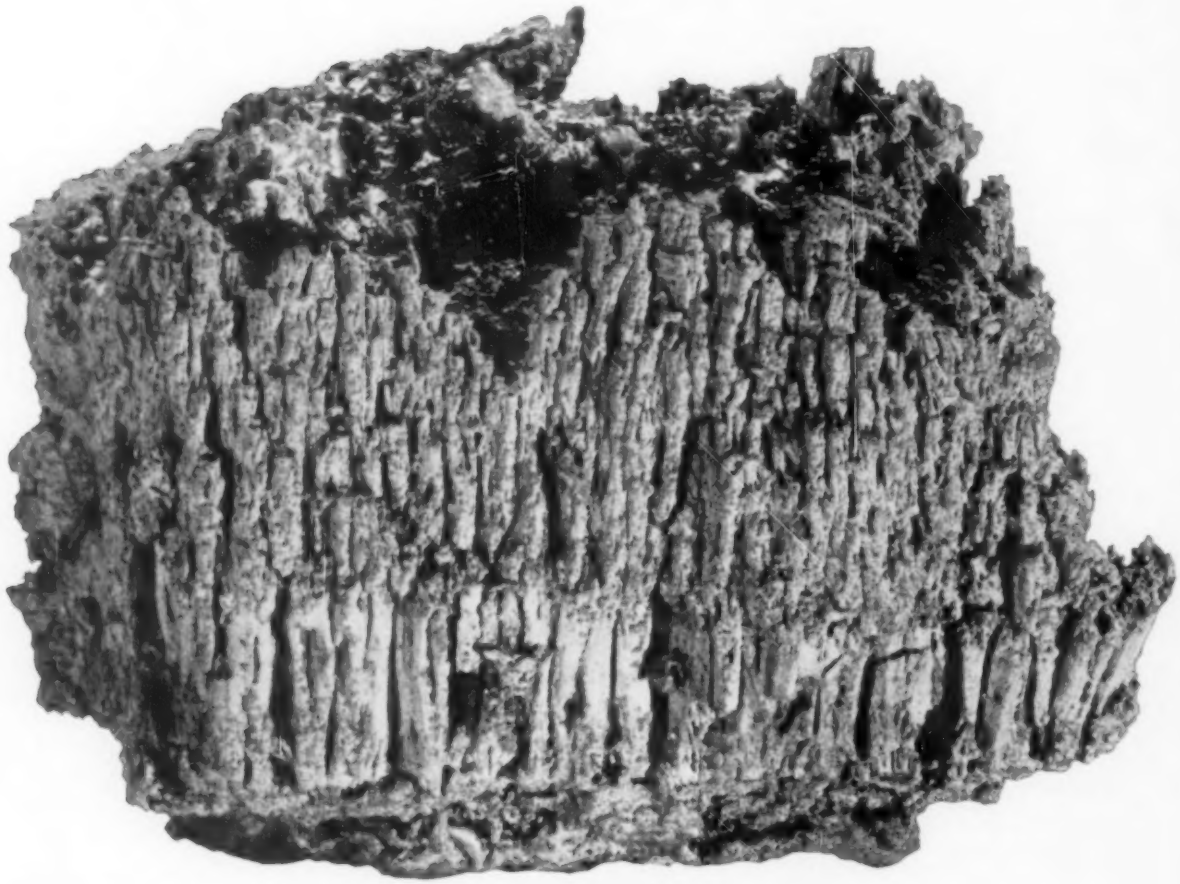

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91-725 R

Donald O. Buker, Assistant Project Engineer, checks on an experimental melt in progress in the Stokes Vacuum Furnace. External controls and alloying devices afford complete access and manipulation of the melt.

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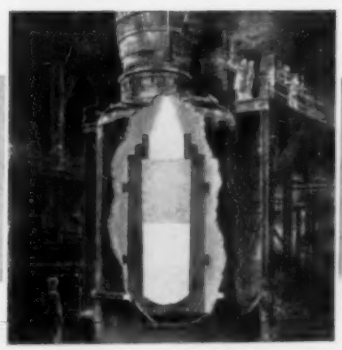

Steam Degassing Systems. Stokes offers production equipment which can control hydrogen content of steel to less than 1 ppm by removing the gaseous impurities from the molten metal.

Vanadium Corporation of America keeps Stokes Vacuum Furnace busy in Ferroalloy Research

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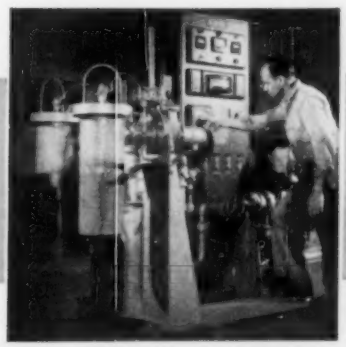

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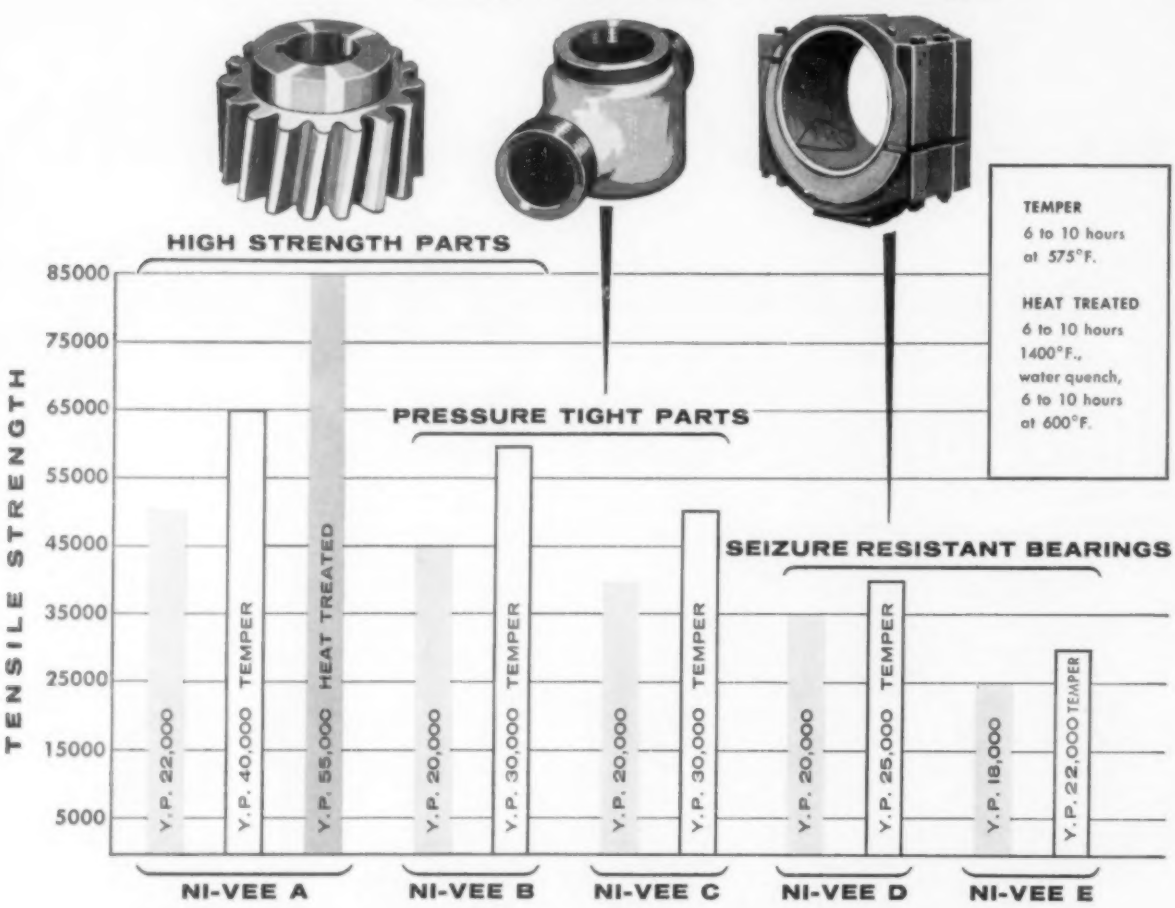

5 high-performance bronzes

These versatile Ni-Vee alloys provide a range of properties that satisfies the requirements of most copper-base castings

The chart shows the range of tensile properties of the five Ni-Vee* bronzes and indicates the types of castings made with these alloys.

As you can see, you can satisfy the majority of your specifications for quality copper-base castings from among these five versatile Ni-Vee materials. Their "As Cast" mechanical properties – especially yield strength – surpass those of comparable G and leaded bronzes and red brasses.

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Ni-Vee extras

You can expect superior performance from all five Ni-Vee bronzes. For example. Ni-Vee B, C, D, and E (the leaded group) can be used for castings of all three classifications shown. Ni-Vee A provides extreme strength. Ni-Vee E gives you extreme resistance against galling or seizure. The low zinc group (Ni-Vee A, B, D and E) show little tendency to dezincify, insure top-notch resistance to stress corrosion. All five, of course, have the excellent general corrosion resistance of copper reinforced by a 5% nickel 5% tin content.

Helpful booklet gives complete information on Ni-Vee bronzes

"Engineering Properties and Applications of Ni-Vee Bronzes" covers tables of composition, charts on deformation, friction, fatigue, elevated temperature service, electrical resistivity, wear and other engineering data. Write for your copy today.

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Alcoa's Surinam Project

Alcoa reports that its long-range aluminum project for Surinam—Dutch Guiana—advanced a step with the draft contract being submitted to the Surinam legislature. It is proposed that the Government would finance the building of a dam and powerhouse to supply power to a 60,000 ton reduction works.

Alcan Deferring Kitimat Expansion

Aluminum Co. of Canada is deferring expansion of its ingot facilities from 770,000 tons to 850,000 tons with the expectation that new production coming into operation during the next year or two will take time to be absorbed. Main impact of the curtailment is to postpone the 80,000 ton capacity expansion at Kitimat, B.C. Capacity there will remain at 180,000 tons.

Kaiser's Expanding Aluminum Capacity

. . . Kaiser Aluminum & Chemical Corp. recently poured the first primary aluminum produced in the Ohio Valley at its new Ravenswood, W. Va., plant. This marks the start-up of a completely integrated operation in which Kaiser will produce aluminum ingots to be rolled into a wide range of plate and foil products. When fully completed in 1958, the plant will have an annual capacity of 145,000 tons of aluminum from four pot-lines, made up of a total of 656 cells.

. . . At the same time the ninth pot-line went into operation at Kaiser's Chalmette, La., plant. Consisting of 144 cells, the line's annual capacity of 27,500 tons will make the plant the largest in the US—247,000 tons annual capacity.

Bauxite Search Moved to the Pacific

. . . In Australia, approval has been granted for the British firm, Consolidated Zinc Corp., to mine bauxite at Cape York peninsula, the northernmost tip of Australia. In the same area Alcan is reportedly seeking mining rights. Reynolds had announced formation of an Australian subsidiary for locating and developing bauxite deposits which might justify establishment of an aluminum industry in Australia.

. . . Panamanian government has granted a subsidiary of Kaiser Aluminum exclusive exploration and mining rights in a large area of western Panama where preliminary studies indicate extensive bauxite deposits.

. . . Harvey Aluminum has concluded a five-year agreement with Japan to purchase alumina for its Oregon plant which is scheduled to go into operation early in 1958. Harvey has also entered into an agreement with the Jamaican government to prospect for bauxite in a 600 sq mile area. Harvey hopes ultimately to transfer its bauxite requirements to Jamaica.

Dow Buys Government Plant

After years of negotiation, Dow Chemical Co. has purchased the Government-owned magnesium facilities at Plant B near Freeport, Texas, for $20 million. The wartime plant has a capacity of 90 million lb of metal per year. Dow operated it for the US government from the time it was put in operation in 1942 until 1945 when it was closed down. Operations were recommended for Government stockpiling in 1951, but since December 1953 Dow has leased and operated the plant.

BELL TELEPHONE LABORATORIES DEVELOPS NEW COMPACT COMPUTER FOR U. S. AIR FORCE

J. A. Githens, B.S. in E.E., Drexel Institute of Technology, and J. A. Baird, Ph.D. in E.E., Texas A. & M., check the control panel of Leprechaun, a new high-speed computer which solves extremely complex problems in one-tenth of a second. Small size and low power are made possible by new design principles and Bell Laboratories' invention of the transistor.

The United States Air Force assigned Bell Labs an interesting assignment: develop a new kind of electronic computer. The major requirement was greater simplicity. Of course, no computer is simple, but this one (known as "Leprechaun" to its designers) is much smaller and simpler than most of the computers currently in use.

It has only some 9000 electrical components; 5000 of them are transistors. As a result, Leprechaun has less than one-third the components of conventional computers. This facilitates testing, experimentation, assembly and service.

Even in its experimental state, Leprechaun is a stimulating example of great strides in the simplification and miniaturization of circuitry . . . a problem of profound interest to all Bell Laboratories researchers as they develop radically new equipment for your future telephone service.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

EDITORIAL

A New Program For Publications of the Metallurgical Society

• In the accompanying editorial, William J. Harris, Jr., Chairman-Elect of the Institute of Metals Division, explains the new publication policy of The Metallurgical Society. The report of the Publications Committee is the result of a year-long study; one of the thorny problems was to solve the financial dilemma of attempting to publish more papers on scientific and engineering research than revenues from dues, subscriptions, and advertising will permit.

• The solution—to publish these papers as a separate publication, TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME, *at a subscription price of $5.00 per year to members and $20.00 per year to nonmembers, was approved by the Board of Directors of The Metallurgical Society on November 6, and by the Board of Directors of AIME on November 20. You will note that Transactions are not included in this issue of* JOURNAL OF METALS, *but that more space is devoted to articles of a general nature. The first issue of the new Transactions Journal will appear in February, and thereafter on a bimonthly basis. Your subscription is invited.*

• Participating in the decisions of the Publications Committee were J. S. Smart, Jr., Chairman; from IMD—W. J. Harris, Jr., J. H. Hollomon, G. A. Roberts; from ISD—John Chipman, Gerhard Derge, G. R. Fitterer; from EMD—S. J. Dickinson, H. H. Kellogg, and P. T. Stroup.

by William J. Harris, Jr.

Publications are the essence of the technical contribution of The Metallurgical Society. Creation of opportunities for authors and members to keep abreast of new developments in all areas of interest to metallurgists is the long-range objective of the publication policy of the Society.

Recognizing the greater opportunity for service offered by the reorganization of AIME, the President of The Metallurgical Society instructed the Publications Committee to recommend a new publications policy consistent with current needs and capabilities. Intensive study of the problem ensued. There was early agreement that publications should present material in the fields of professional interests, metal science and metal engineering. Expansion of space for information dealing with the engineering aspects of the production, fabrication, and utilization of metals was a principal objective of the new policy. Proposals were offered by the divisions of the Society and by members of the Committee and of the Society for media that would satisfy these needs.

Serious consideration was given to a proposal that there be three journals, one dealing with each of the three fields: professional interests, science, and engineering. However, in recognition of the desire of many members to have science and engineering technical papers combined, and in recognition of the need for a scheme that appeared consistent with our financial capabilities, a program of publication based on two journals was finally accepted. One of these journals will be the JOURNAL OF METALS. Material presented in this journal will be controlled by a professional editor on the staff of the Institute. Subject matter will include papers on professional and economic subjects, review and summary articles in metal science and engineering, abstracts of technical papers to be presented at regular meetings of the Society, and discussions of the broad problems of concern to all members of the Society.

The second journal will be called TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME. In this journal will be presented technical papers on subjects in the fields of metal science and metal engineering. The technical papers presented for publication will be reviewed by the technical review committees of the three divisions in The Metallurgical Society: EMD, ISD, and IMD. The general operations will be handled by an editor serving on a part-time basis.

The program of publication and distribution adopted for the immediate future includes a change in the distribution pattern and in the charges for the publications. All members will receive with their membership the JOURNAL OF METALS, a monthly publication. On payment of an additional $5.00 per year, they will receive the TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME on a bimonthly basis. Bound volumes will be available after the end of the year for $5.00. Accordingly, the program contemplated will give members two journals and several hundred more pages than they presently receive, for a cost approximately equivalent to the present cost of membership and the cost of permanent binding of the Transactions.

Rates for nonmembers are being substantially increased. While a charge of $8.00 will be continued for a subscription to the JOURNAL OF METALS, a charge of an additional $20.00 will be made for a subscription to the TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME.

While the new publication policy is being launched—the first issue of TRANSACTIONS to appear in February, 1958—the Metals Research Publications Fund will be continued to absorb such losses as may ensue, during the first year or two of operation. Projections indicate that the new publications policy will probably result in a publications program that is financially self-sufficient.

The Metallurgical Society is cognizant of its great responsibility to provide a service to all American metallurgists. In the past, emphasis has been on metal science, with some material presented on professional matters, and only a limited amount on metals engineering, particularly the fabrication and utilization of metals. The new publication policy was arrived at as the most effective means of providing increased services, especially in the field of metallurgical engineering, with journals that have great potential for operating with no deficit.

The Metals Branch and its predecessors within AIME have undergone, during the past ten years, a number of changes in publications program; none of these changes was based on as thorough and detailed a study as has resulted in the present program, but each of the changes has been made for the purpose of increasing services to members. The new policy recognizes the new status of the Society and has been adopted with recognition of as many points of view as were reflected by participants in the planning and approval of the program. The Board of Directors of the Society sincerely hopes that the new policy will provide greater service to members, and will eliminate the continuing deficit. Comments, suggestions, and criticisms are always welcome, and should be addressed to the Secretary of the Society, Robert W. Shearman, at the New York headquarters.

TRANSACTIONS

OF THE METALLURGICAL SOCIETY OF AIME

In 1958, Transactions of

- *Iron and Steel Division*
- *Extractive Metallurgy Division*
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will appear in a *New Journal* **TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME.** Appearing on a bimonthly basis, more than one thousand pages of engineering and scientific material will be published during 1958—a substantial increase over the Transactions of former years.

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METALLURGICAL SOCIETY OF AIME
AI ME

HOOVER ON EDUCATION

The United Engineering Center fund drive got off to an impressive start as former President Herbert Hoover made a powerful plea, not only for the new building, but also for new engineers. As the deficiencies in metallurgical manpower can not be put in perspective without realizing the deficiencies in our primary and secondary schools, the JOURNAL OF METALS *takes pride in presenting the text of our former President's remarks.*
• *Indicative of AIME's interest in this vital area, a special Symposium on Metallurgical Manpower is being planned for the Annual Meeting in February.*

by the Honorable Herbert Clark Hoover

TODAY marks the launching of a drive by the United Engineering Societies for the funds to erect a new building. We need the support of all our members. And especially do we need support from industry.

The activities of these societies are of vital importance to the American people, to the engineers and to the industries.

We have about 200,000 engineer members in these societies, and the membership is constantly increasing. We are overcrowded in our present headquarters. It has become clear that we must have more room if we are to effectively conduct what has become one of the nation's greatest educational centers.

Our library—the greatest engineering library in the country—is overflowing. Our present building is inadequate to provide for the great meetings of our members. At these meetings new steps of progress in engineering are presented to the world and the road to further advance over new frontiers is illuminated.

Effect of Sputnik

You no doubt have listened to the recent explosions over the failure of our educational system to provide this country with adequate scientific and engineering staff. I need not tell you that for ten years the engineers of America have been relating our agonies over this to everyone who would listen.

It seems that it required Sputnik to awaken the country to certain facts of life. The answer, however, is not more Sputniks, but something right down to earth.

The subject has been investigated, reported upon, and its critical necessity thundered by the scientific and engineering professions during all these last ten years. I am not going to repeat the statements of our committees or even my own shrieks of alarm during these years.

The trouble is that we are turning out annually from our institutions of higher education perhaps fewer than half as many scientists and engineers as we did seven years ago. The greatest enemy of all mankind—the Communists—are turning out twice or possibly three times as many as we do.

A personal statement of views

I am going to state bluntly my own views as to one of the major causes of our predicament. One of the roots of our problem is in our high schools. Today they are turning out more than 1,500,000 graduates annually. No one can tell me that these youngsters are of less mental ability and ambitious character than the youngsters were ten years ago.

Unless we have so degenerated in those racial qualities beyond saving our American way of life and our national defense, there must be 60,000 or 70,000 more young men and women of this quality and ability who could be channeled into these professions every year.

Our higher institutions of learning have the capacity to train the recruits we need. The harsh fact is that the high schools are not preparing youngsters for the entrance requirements which must be maintained by our institutions training scientists and engineers.

The origin of this deficiency is well indicated by a careful sampling taken not too long ago, which showed that under 12 per cent of the high school students were being taught the elements of algebra and geometry; something under 7 per cent were be-

Architects sketch of the United Engineering Center, as seen from the United Nations' Secretariat building. Scheduled for completion by the fall of 1960, the 10 million dollar structure will be the headquarters for a quarter of a million engineers in 16 engineering societies.

ing taught elementary chemistry and under 5 per cent were being taught elementary physics.

And this wretched record has further implications than simply the failure to produce the professional skills. We live in an age where every side of our daily life touches on physics, chemistry and mathematics. No youngster stepping into maturity can enjoy or, in fact, adequately live in our civilization today without some training in these sciences.

But beyond this essential education of our youngsters is the pressing question of more scientists and engineers. In my view there is a fundamental weakness from the too prevalent high school system of allowing a 13- or 14-year old kid to choose most of his studies. Academic freedom seems now to begin at 14.

Need for guidance stressed

A youngster's first reaction in school is to seek soft classes, not the hard work of science and mathematics. Also, he has a multitude of extra-curricular activities which he considers more beguiling than hard work. You simply cannot expect kids of those ages to determine the sort of education they need, either for daily living or for the professions, unless they have some guidance.

Once upon a time, our curriculums in high schools provided a minimum of certain essential subjects and still left the youngsters a wide area for supplementary choice. Such curriculums are not strange to our civilization, for they are today insisted upon in our universities and technical institutions as fundamental to the training of men and women.

We are told that there are not sufficient numbers of teachers for even minimum instruction in science in our high schools. We are told that our teachers are under-paid. We are told that there are insufficient elementary laboratories. This is all true.

But if this nation is not to degenerate intellectually and to lose its strength for daily life and defense against our enemies, the taxpayers, school boards, the Parent-Teachers Associations had better wake up.

Now that we have plenty of buses and streetcars, one of the remedies would be to consolidate some of our high schools in more of the larger cities into institutions for the special training for the entrance requirements of our universities and technical institutions.

Another remedy is an appeal to engineers and scientists by the school authorities to volunteer two or three lessons a week in the schools of their own localities. Two or three hours a week with eager kids is recreation—not a tax on professional work.

We are also told that the cost of training in our universities and technical schools has risen beyond the reach of sufficient numbers for the national supply. That is also true, and industry is striving generously to remedy the situation.

Scholarships are not enough

However, if we are to refill our vacant university and technical institutions which train engineers and scientists, it cannot be done by offering scholarships—as helpful as they are. It requires also sufficient preparatory training for them to enter institutions of higher instruction.

The parents in this country are allowing talented youngsters to be educated as desk workers—a career already overcrowded—at less future pay than they can earn as a bus driver. And this at a time when the scientific professions yield great rewards and great dignity.

But this is an old story to all engineers, and we are grateful to Sputnik and to President Eisenhower for his vigorous statement of this national need.

In ending, I will return to the first purpose of this meeting—a proper and stimulating home for the engineers of America.

by W. J. Harris, Jr.

U.S. PROGRESS IN TITANIUM DURING 1957

Sponge capacity now 27,000 tons per year . . . continuous cold strip rolling with few intermediate anneals . . . three commercial heat treating techniques . . . a number of new alloys . . . increased competition from other metals.

PROGRESS in titanium during 1957 can only be measured by comparison with the past and projections of the future. This metal has been much discussed during the ten years since a commercially attractive process for production of ductile titanium was discovered. There has been substantial progress in terms of these comparisons: quality has improved, properties are at higher levels, and new alloys have moved from the experimental to the production stage. In addition, cost has been reduced. However, there has been a substantial reduction in production requirements for the balance of 1957 and this will continue for the next few years. This reduction in requirements is only in part the result of purely technical considerations; it is largely a result of military policy and fiscal considerations. These factors are of major importance because titanium usage is largely of military interest at present.

Any attempt to summarize progress would, of course, fail in one degree or another to reflect specific situations with complete accuracy. A material that has primarily a military application, but is supported to an increasing extent by private capital investment, is a relatively rare commodity in this country. The complex relations of Government and industrial planning are reflected in all aspects of the titanium situation. In 1957, the technical progress and the effectiveness of industrial response to stated Government needs represent at least two of the most interesting new developments.

. . . in production

Turning to specific information, it is important to note that the tonnage of mill products produced in 1956 was less than 2000 tons. During 1957, more than 5000 tons were produced. A continuing projected increase in production, presented to industry in 1956, was reflected in the investment by industry of substantial funds in new melting and rolling facilities. During 1957, integrated facilities designed for titanium became available for the first time in the history of the metal. Through Government support and some additional industrial investment, the capacity for sponge production has now reached a level of 27,000 tons per year. The capability of the industry to meet an expanding production requirement is reflected by these levels of capacity and by the willingness on the part of industry to create new facilities.

It is recognized and accepted that the consumable electrode melting technique can produce material of satisfactory uniformity. Accordingly, the pressure to devise new melting techniques has not been as great as was predicted a few years ago. However, the need to utilize scrap and to produce large, shaped castings requires continued effort to develop skull-melting practices.

. . . in rolling

The rolling of titanium has seen notable advances during 1957. It is now possible to produce continuous cold strip with perhaps only one, or a very few, intermediate anneals in going from sheet bar to 0.020-in. sheet. Cold rolling reduces contamination and therefore minimizes losses in pickling. It has a tendency to improve surface quality and flatness as well. Certain high strength alloys have also been strip rolled to gages of 0.001 in. in 4 to 6 in. widths. Heat treatment of titanium barstock and forgings became a commercial reality during 1957, and heat treatment of sheet advanced rapidly.

. . . in heat treating

There are several interesting approaches to the heat treatment of titanium alloy sheet, and these are currently being explored on a production scale. Ten years ago, interest in titanium grew out of its potential for use up to about 800°F with room temperature strengths above 150,000 psi. This potential has been realized by heat treatment involving quenching and subsequent aging. Three methods are being utilized for heat treatment of commercial sizes of sheet. The first involves the enclosing of titanium sheets in steel envelopes and the heating and quenching of the partially evacuated envelope. Contamination is reduced and flatness can be maintained at an acceptable level. A modification of this practice, based on coatings, has not been developed to the same extent. A second method involves the

W. J. HARRIS, JR. is Executive Director, Materials Advisory Board, National Academy of Sciences, National Research Council. Paper presented at the AIME Titanium Symposium, Chicago, November 1957.

resistance heating of sheet under slight tension followed by spray quenching. The short time of heating permits the use of uncoated material without excessive contamination, and the tension maintains required flatness. A third process, now at the commercial scale, involves use of a roller hearth furnace holding the sheet between rolls, and spray quenching as it moves through the rolls. Aging in resistance heated platens permits creep flattening. Rapid quenching rates are maintained in the second and third processes. All of these processes have been applied to 36 x 96 in. sheet in experimental quantities during 1957. Any of these processes may emerge as commercially attractive, and each of them has the potential for producing preliminary quantities of heat-treated sheet for evaluation.

. . . in fabrication

The fabrication of titanium into aircraft components has moved during the last two or three years from the hand reworking of every part to the production acceptance of the material, with losses reported to be no greater than those of other materials. No special advances appear noteworthy during the past year, but significant progress is, nonetheless, evident from the reduction in rejection rate and in scrap losses due to more uniform quality.

. . . in alloys

During 1957, a number of new alloys have moved toward the production stage, including the heat-treated alpha-beta alloys in the Titanium Sheet Rolling Program, as follows: the 4Al-3V-1Mo alloy, the 16V-2½Al alloy, and the 6Al-4V alloy. All-alpha alloys of higher creep resistance than the 110A alloy have been introduced and are being evaluated. All-beta alloys have been produced in limited quantities for evaluation. An alloy not in the Titanium Sheet Rolling Program, but having equivalent heat treated strength, the RS-140 alloy, has shown promise for certain applications in which a very soft solution-treated condition is not required.

Cost outlook

It is difficult to speak precisely on the subject of changes in costs of titanium during 1957. The price of high quality sponge has been reduced from a level of about $2.75 per lb to a level of about $2.25 per lb. It appears that the composite price of products has been reduced from about $12 per lb to about $10 per lb. Some producers have indicated willingness to consider much lower prices for forging billet. Further reductions in cost may be affected by the reduction in projected requirements for titanium.

Temperature and weldability limitations

As far as technical aspects are concerned, major problems standing in the way of wide utilization of titanium are its limited weldability in high strength sheet materials and its temperature limitation of about 800°F. In addition, of course, the cost of titanium in comparison with competitive steels is a major factor that affects its use.

Competition from steel

The titanium industry and titanium alloys have fulfilled most of the technical promise originally held out for them. On the other hand, titanium now faces increased competition from steel, and it may eventually find competition from beryllium, at least to an extent not predicted several years ago. Steel has the advantage of acceptable weldability and of much lower cost. Thin, high-strength steel alloy strip, of the order of 0.001 in., is available. Therefore, steel is finding a place in sandwich construction—a type of construction of great interest in advanced airframe designs. Because of lack of availability until very recently of thin strips of titanium, and because of its limited weldability, titanium has not appeared so promising for this application. This competitive situation does not affect the present market, but rather the future demand for titanium.

The Government's point of view

There has been a substantial reduction in the stated production requirement for titanium. This cutback in programs has been a result of a reduction in orders for the weapons systems in which titanium was employed, or a cancellation of these systems. The reductions, for the most part, have been the result of stretch-outs in the military program and the shift from procurement of aircraft to missiles. The reduction in military requirements for titanium has resulted in very aggressive efforts to increase civilian consumption. These efforts are proving, at least in a limited sense, to be successful.

From the Government's standpoint, the development of titanium has provided a material of great interest for aircraft applications. At the same time, the development of titanium has resulted in development by the steel industry of competitive alloys of significant present and future potential in applications to aircraft and missiles. It does not appear likely that these alloys would have been developed at the same rate if the titanium developments had not been vigorously pursued. The concurrent encouragement of increased production of nickel required in the high-strength steels has made possible the consideration of these materials.

Much has been learned from titanium regarding the steps that must be taken to create rapidly a basic metals industry. Much information concerning relations between government and industry has been provided that may be exceedingly valuable if other materials of limited industrial potential are developed. In particular, the encouragement to development of new alloys provided by the Titanium Sheet Rolling Program in support of the transition from laboratory to production may suggest techniques applicable to other metals or materials.

The year 1957 has seen the development of titanium as a material fulfilling much of the promise anticipated only ten years before. It has seen a changing pattern of weapon design and procurement, resulting from technological development in other areas, interrupt an otherwise continuously upward trend in consumption of titanium, and result, at least temporarily, in the unemployment of facilities producing titanium. These facilities may be used to advantage for production of other metals. If the titanium industry had not been supported, it is not likely that designers would have the same confidence today in proceeding with the design of high performance systems. The program on titanium and the competitive response of the steel industry during 1957 represents significant progress on materials of present military importance and potential civilian interest.

by Eric Swainson

TITANIUM IN BRITAIN AND THE CONTINENT

Titanium sponge, ingot, and fabricated forms are now produced commercially in France, Western Germany, and Britain. In addition, pilot plants have been operated in Sweden, Italy, and Austria, and commercial production may have started. Norway, Switzerland, and Belgium are among countries in which research and development work has been carried out.

TOTAL European raw titanium capacity probably amounts to just short of 2000 tons per year, with Britain providing more than three quarters of this.

France

In France, capacity, presumably for sponge, has been quoted as 200 tons per year. It is believed that this is at present in excess of requirements, but the plant has been laid down so that it can rapidly be expanded up to 1000 tons per year. Each of the two companies principally concerned apparently has facilities for sponge production, melting, and fabrication.

There is little information about the usage of titanium in France. At the International Aircraft Salon at Le Bourget in May 1957, forms of titanium displayed included small alloy forgings, including turbine compressor blades, bar stock and coils of wire, C.P. strip and sheet, hydraulic tubing, a single extruded section, and a welded vessel. No large pieces of titanium alloy sheet were on view. It can probably be safely presumed that some titanium will be incorporated in many of the new fast fighter-type aircraft which have been developed in France.

Germany

Two companies appear to be interested in sponge production in Germany, but output is very small, probably no more than 5 tons per year. A somewhat larger amount of raw titanium has been imported, mainly from Japan, and at least five companies have undertaken melting and fabrication of this material.

In the absence of an aircraft and aircraft engine industry in Germany, attention in that country is being directed mainly to applications of titanium in the chemical industry. Specific technical interests therefore include the effect of alloying constituents on the corrosion resistance of titanium, and methods for the fabrication of chemical plant, including lining of steel vessels with titanium. Most of the normal fabricated forms of titanium, including CP strip, tube and wire, and alloy forgings, are produced by one or other of the German companies engaged in titanium fabrication.

Great Britain

In Britain, Imperial Chemical Industries is the principal producer with a raw titanium plant of 1500 long tons per year capacity and associated melting and fabricating facilities. In addition, a small raw titanium plant has been operated by McKechnies, and a melting plant of some 300-400 tons per year capacity is operated by Wm. Jessop. The British government has undertaken to purchase 75 pct of the output of the I.C.I. raw titanium plant for a limited period at a price not exceeding world price. There is no Government support for melting and fabrication, and all titanium facilities have been provided entirely with private capital.

Aircraft applications

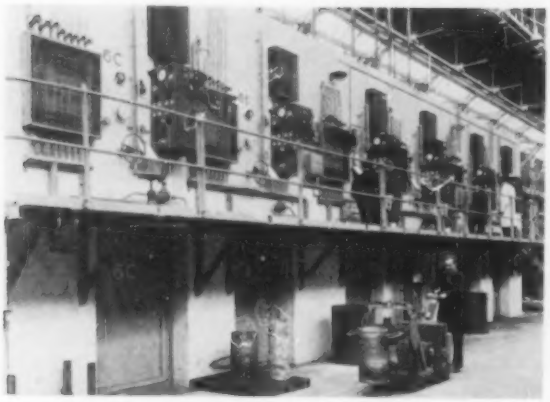
The major demand for the titanium produced in Britain is, as would be expected, from the aircraft and aircraft engine industry. In 1956, of the titanium sold by I.C.I., 40 pct was rod for gas turbine compressor blades, 20 pct was sheet for firewalls, 20 pct sheet for exhaust and jet pipe shrouds, 5 pct billet for discs and spacers and 5 pct bar for small forgings, fabrications etc. The use of titanium for gas turbine compressor blades is firmly established in Britain, particularly in the Rolls-Royce Avon engine, and there seems every possibility of this application continuing and expanding as new engines are developed. Titanium has so far not been used for compressor discs in production engines in Britain, for although the technical advantages are apparent and well known, the low yield of finished discs from the initial forgings makes them extremely expensive. Considerable attention is now being directed to developing improved methods of disc production which will result in a higher utilization of metal and allow titanium to be substituted for steel without a prohibitive increase in cost.

Titanium is also being used in airframe construction in a number of aircraft in Britain, although the average weight incorporated per aircraft does not appear to be as high as in the U. S., and, with a few exceptions, it is used mainly for non-stressed or only lightly-stressed components. About 1½ tons of CP sheet is being supplied for each Bristol Britannia aircraft, and is used for exhaust pipe shrouds, engine bulkheads, and for parts of the engine nacelle. Somewhat similar use of titanium in other British civil aircraft is expected.

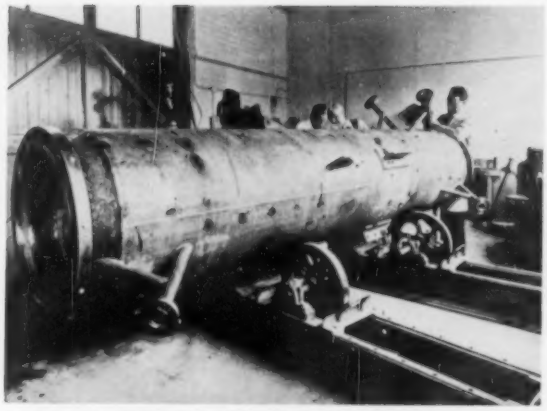
Non-defense applications

Great efforts are being made in Britain to stimulate uses of titanium outside the aircraft and aircraft engine industry. These efforts were given added urgency by the Government defense policy, announced in April 1957, of restricting the development of new manned aircraft and concentrating on missile pro-

ERIC SWAINSON is Assistant Manager, Technical Dept., Metals Division, Imperial Chemical Industries Ltd., Birmingham, England. Paper presented at the AIME Titanium Symposium, Chicago, November 1957.



Blast-protected, remote-control furnaces such as these, at ICI's Kynoch works, produce titanium for Britain's industry. The finished products take many forms. . .



. . . Such as this mild steel vessel lined with CP titanium by welding. Used for handling organic acid solutions, it is 2¾ ft in diam, 15 ft long, and has six branch pipes. . .

duction—a decision which considerably reduces the potential requirements for titanium in the British aircraft industry. Although over 90 pct of British titanium is still employed in aircraft, the response to attempts to increase its use for other purposes is not discouraging. Two promising applications of titanium in the electrical industry are as end bells for turbo-alternators and low pressure rotor blades in steam turbines. The use of CP titanium for surgical fittings is rapidly becoming established in Britain, although quantities involved are, of course, small. Anodizing jigs represent another small but established use.

However, the greatest potential demand for titanium outside aircraft and aircraft engines, in Britain as in America, is in the chemical industry. The figures are intended to give some idea of both the type of applications achieved and the range of titanium products made in Britain.

Technology based on U. S. development

Any statement on the European contribution to titanium technology should, of course, include reference to the facts that the iodide dissociation method by which it was first demonstrated that titanium was ductile was developed by the Phillips Laboratory in Holland, and that Dr. Kroll devised the magnesium-reduction process while working in Germany and Luxembourg. The subsequent effort and resources devoted by the United States to establishing titanium production on a commercial basis and to developing the technology of titanium and its alloys has, of course, been many times greater than that which has been carried out by the rest of the free world. Titanium producers and users in Europe certainly recognize the enormous value of the work carried out in America, and freely acknowledge that the American effort has provided virtually the whole basis of current titanium technology. This is not to say, however, that the European effort has been inconsiderable; for instance Imperial Chemical Industries in Britain is currently spending £ 250,000 per year on titanium research and development, excluding work on extraction and refining processes.

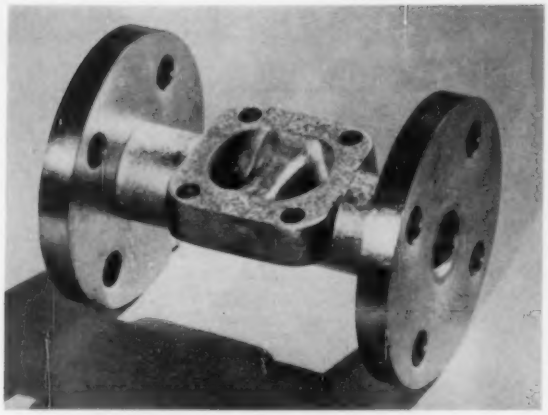
In considering European technical progress, reference must first be made to similarities rather than differences between European and American practice. Thus, in each of the three principal European countries, titanium is produced by chemical reduction of the tetrachloride, melted under vacuum in consumable electrode cooled crucible arc furnaces, and fabricated to sheet, forgings and rod by methods essentially similar to those in the U. S. The ability to carry out these operations after only a seven or eight years' acquaintance with titanium is the best testimony to the progress made in Europe, and this would be true even if European practice followed American practice slavishly in all details. In fact this is not the case, for in many respects European developments have been independent of American work, and although in some cases the same solutions have been arrived at, in others different answers have resulted.

Sodium reduction, a British contribution

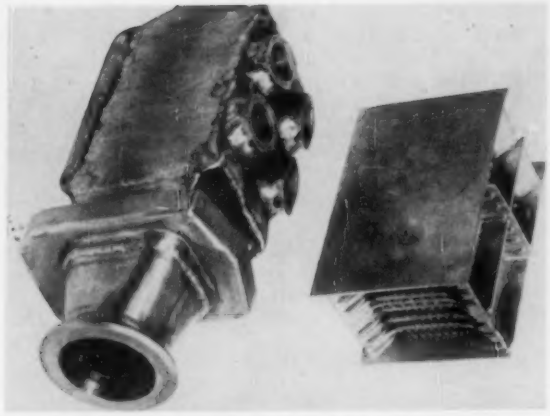
Perhaps the most important single European development is that of the sodium-reduction process for the production of raw titanium which I.C.I. pioneered in Britain, and which was put into full commercial operation in 1955. The process is similar in many respects to the Kroll process; sodium and titanium tetrachloride are contained in a sealed steel vessel under an argon atmosphere and are maintained at a temperature of 800° to 900°C so that they react to form metallic titanium and sodium chloride. When the reaction is complete, the vessel is allowed to cool and the titanium is separated from the sodium chloride by leaching.

The purity of titanium produced commercially by the sodium reduction process is generally similar to that of Kroll titanium, and average melted hardness is normally 130 Vickers, equivalent to 110 Brinell using a 1500 kg load and 10 mm ball. As with the Kroll process, purity has been improved considerably during the last two or three years, due to the use of higher purity raw materials and improved detailed design of reduction plant. It has been stated that, in the United States, titanium with a hardness as low as 70 Brinell has been produced by sodium reduction of the tetrachloride, and it may be that hardness of commercial material could be reduced towards this figure if this were made necessary by the development of alloys which required very pure titanium.

The relative economic merits of the sodium- and magnesium-reduction processes depend to a considerable extent on the availability and relation in price between sodium and magnesium. In Britain, the sodium process is more attractive, and mainly as a result



. . . This 1 in. Saunders valve, cast in a semi-permanent graphite mold, is to be used in a plant producing synthetic fibers. . .



. . . A heat exchanger, furnace-brazed in an argon atmosphere with silver base alloys, is still in the experimental stage, but shows much promise.

of the use of this method is has been possible consistently to match American sponge prices despite the lower level of British output. Moreover there are technical reasons for believing that the sodium process has a greater potential value. It is probably easier to bring sodium to a high state of purity than magnesium, and it is possible to handle sodium in the liquid state, which considerably simplifies the loading of reaction vessels. An important advantage of the sodium process is that the product is readily amenable to purification by leaching. The reaction product of the magnesium reduction process can, of course, be purified in this way, but the magnesium must be dissolved in acid rather than water, and in this operation hydrogen is liberated, some of which enters the metal. Also magnesium oxychloride is formed which is insoluble and may precipitate and contaminate the titanium. To avoid this great care is necessary, and if the highest quality raw titanium is to be produced, it is generally preferred to purify the reaction product of the magnesium reduction process by vacuum distillation. Intrinsically, this is a more costly process than leaching; it cannot be operated continuously; and the titanium sinters during vacuum treatment into a relatively strong mass which must subsequently be crushed and is finally produced in the form of coarse lumps. On the other hand, purification of the reaction product from the sodium reduction process can be accomplished by continuous leaching with relatively little difficulty, and titanium can be produced in a granular form which is very suitable for handling, homogenization, mixing with alloying constituents and scrap, and compacting. Currently I.C.I. are incorporating 40 to 50 pct scrap in CP and low alloy ingots, and 30 to 40 pct in high strength alloys.

The method of melting titanium employed in Europe is essentially the same as that used in U. S., namely cooled-crucible, consumable-electrode, vacuum-arc melting, and indeed to a considerable extent, European practice has been based on information obtained from America.

Advances in furnace design

A number of features of recent and current European work on melting are worth noting. Because of explosions during melting reported from U. S., and one explosion in a research furnace in Britain, new furnaces are being installed in protective cubicles, and operated entirely by remote control. As individual furnaces become larger and more complex and therefore more costly, attention is being paid to methods and devices by which down-time between melts can be reduced and therefore utilization of furnaces and electrical equipment increased. Another aspect of melting which has received considerable study has been the means of producing primary consumable electrodes. As a result, cheaper alternatives to the established method of pressing individual compacts and welding together with a titanium wire welding torch have been devised. Until the last year or so, titanium producers developed, designed, and had made their own melting furnaces, but more recently one or two specialist furnace builders have emerged, and because of their previous experience of vacuum technology and electronics, are able to offer equipment of extremely good detailed design and performance. In particular, the German company of Heraeus GmbH produces furnaces having an electrode control device which has important advantages over the normal methods of adjusting the electrode position by reference to arc voltage or melting time.

Ingot surface requires no machining

The quality of arc-melted titanium ingots currently produced in Britain is such that machining before fabrication is not normally necessary. At the present level of output of titanium wrought products in Europe, forging is preferred to roll cogging as the method of ingot breakdown; forging and extrusion billet, bar for rod and wire production, and slab for rolling to sheet are made by this method. Preheating before most hot-working processes is carried out in electrically-heated furnaces having an air atmosphere in order to minimize hydrogen contamination so that a maximum hydrogen content of 0.015 pct is held without the necessity of final vacuum degassing. Slab, bar, and billet are machined generally or locally before further fabrication in order to ensure the best possible surface finish of final products; they are inspected by visual, ultrasonic, and gamma-radiographic methods.

Sheet surfaces need improvement

Although practices for strip/sheet rolling of commercially pure titanium have been devised, most sheet is made by single-sheet rolling on large 4-high

mills, cold for unalloyed and hot for alloyed titanium. An exception is the rolling of strip down to 0.0025 in. for experimental production of heat exchangers and honeycomb structures. Surface finish and dimensional tolerances of alloy sheet are still inferior to other materials used in aircraft construction, and in this respect, there is considerable scope for improvement in fabrication methods. For rod production, an advanced mill of Swedish design, with roller guides and repeaters, capable of finishing speeds of over 2000 ft per min, has recently been installed in Britain and is expected to yield an extremely accurate product with the minimum of losses in subsequent centerless grinding operation.

Tube production stalled

Commercially pure titanium tube is produced by extrusion of hollow billets followed by tube reduction and cold drawing, but use of such tube in aircraft hydraulic systems has been delayed by its variable, and at times poor, fatigue life when subjected to pulsating pressure tests. It has been established that failure under these conditions is initiated by mechanical tears and imperfections in the bore of the tube which arise during extrusion. Methods of removing these defects have recently been devised, and it is now expected that solid drawn titanium tube of excellent fatigue characteristics will shortly be produced commercially. As far as is known, there is no production of welded tube in Europe.

Shaped castings need a market

A considerable amount of work on the production of shaped titanium castings has been carried out in Britain. Originally a bottom-pouring, arc-melting furnace was employed, but it proved difficult to control the temperature and amount of metal poured, and for the last three years a lip pouring furnace of about 100-lb capacity has been used, initially with graphite and subsequently with a consumable electrode. Castings are now being made in semi-permanent graphite molds on a small commercial basis. Work on alternative mold materials is continuing, but the stage has already been reached at which the decision on whether to install equipment for full-scale commercial production of castings depends more on favorable assessment of the potential market than on overcoming technical limitations of the process.

Welding and brazing

The welding and brazing of titanium have received much attention in Europe, and a number of papers have been published. Although closed-chamber techniques are also employed, a special feature of British work on argon-arc fusion welding was the early development of techniques for welding quite complex components in the open air. European and American work on the brazing of titanium appears to have progressed on similar lines. For furnace-brazing in an argon atmosphere, silver-base alloys are used if brazing cycles can be kept short, while for longer brazing times, eutectic ferous titanium alloys or nickel or copper foil are employed, and the joints freed from brittle eutectic alloys by a suitable diffusion treatment.

New alloys available

The range of titanium alloys marketed in Europe is generally similar to that in the U. S., but one important exception is that a relatively mild alloy containing 2 pct Mn and 2 pct Al is produced by both I.C.I. and Jessops in Britain and, as the principal compressor blade material, accounts for a substantial part of the total titanium output. The alloy was developed by I.C.I. some four or five years ago to replace the hardest grade of commercially pure titanium then produced with a material of equal strength but better ductility and working properties. At a tensile strength of 50 tons per sq in. it has 20 to 30 pct tensile elongation, and is preferred to the 4 pct Mn-4 pct Al and 6 pct Al-4 pct V alloys where it is possible to sacrifice some strength for greater ease of working and manipulation. It is perhaps surprising that this alloy or its equivalent has not found application in the U. S.

Alloy research

Much work has been carried in Britain aimed at developing titanium alloys having improved creep strength at moderately elevated temperatures. The British Non-Ferrous Metals Research Association has obtained promising results from titanium-aluminium-zirconium alloys; Jessops have developed an alloy designated Hylite 50, described as a complex aluminium-molybdenum alloy; and I.C.I. have produced a high tin, low aluminium alpha alloy, Titanium 371. Although the creep properties of all these materials appear attractive, their use to date has been limited. In the case of Titanium 371, evidence has been shown of structural instability at elevated temperatures, and further work is being undertaken to determine what modifications in composition are necessary to overcome this. German investigators have made a considerable contribution to knowledge of the effect of alloy elements on the corrosion resistance of titanium. Much theoretical study of the alloying behavior of titanium and the constitution of titanium alloys has been carried out in Germany and Britain. Finally, a great deal of work has been done on determining the properties of titanium and titanium alloys, and this has included fairly full studies of creep, fatigue, notch fatigue, corrosion resistance, and corrosion fatigue characteristics.

The old bugaboo—high cost

The present overall titanium situation in Europe is perhaps not vastly different from that in the U. S. We know how to produce raw titanium of high purity, how to melt it into sound ingots, and how to fabricate these ingots to most, although not all, of the final forms required. We can make some good titanium alloys, and we have established some firm applications for them, predominantly in the aircraft industry. The major present limitation is that we can do these things only at a very high cost, and consequently the demand for titanium is relatively small, and can adequately be met by the production facilities already installed.

European producers must now on the one hand improve the quality of their products and alloys so that the use of such an expensive metal as titanium can be more readily justified, and on the other hand reduce their production costs. Although these seem hard tasks, we derive some confidence from the past record on titanium and we believe that despite temporary set-backs, we are nearer to a stable, useful and economic titanium industry in Europe than could reasonably have been predicted ten years ago.

by John P. Nielsen

Soviet Titanium Research and Production

An exclusive interview on what the Russians are doing about titanium as revealed by Dr. John P. Nielsen, Chairman of the Dept. of Metallurgy of New York University, who recently returned from his second tour of metallurgical research laboratories and plants in the USSR.

THE technical literature of the USSR gives evidence that Soviet metallurgists in 1950-51 became aware of the vast titanium program that started in the US about 1948. Titanium metallurgy research in the USSR appears to have begun about 1953, and today there is a large-scale research program for titanium in Russia.

Substantial activity on titanium

Almost every important metallurgical laboratory has from one to thirty people working on titanium. For example, a laboratory specializing in steel will have one, two, or three people that are assigned to titanium problems, or a non-ferrous laboratory, concentrating on aluminum, will have a group working on titanium.

There are four of five chief laboratories working on titanium. One is the Baikov Institute for Metallurgy at the Academy of Sciences, another is the Central Scientific Research Institute for Ferrous Metals, a third is the Institute for Aircraft Materials, and a fourth is the Institute for Rare Metals in Moscow. The latter has been significant in developing laboratory techniques on the Kroll process and from there, presumably, into pilot plant and production techniques. Titanium research has permeated all the metallurgical laboratories that could be seen, and the conclusion is that the Soviet Union is betting on titanium extensively.

Titanium sponge—adequate quality, unknown quantity

The Soviet Union apparently has a high level of titanium production, but they will not give out figures on output. Also, the number of plants making titanium in the USSR is not known, but there is one plant in the Moscow area, and there are reportedly two plants that are quite some distance away. Ilmenite slag is their raw material.

They have come across the same types of problems as American titanium metallurgists. Perhaps here and there they have penetrated the technology further than we have. As an example, their mineralogy work on slags appears to be as well if not better developed than in the US. However, they have not gone further along the whole front.

When one asks about the quality of sponge, they say that it is comparable to that in the US, and when we asked what the Brinell hardness is, they indicated that it is something on the order of 150 to 180 Brinell, and that it is getting better all the time—the same sort of comments you hear in this country. I am inclined to think that their sponge is somewhat inferior, or at least not superior to that in the US. Some samples of sponge given to us were analyzed, and from this it does not appear that they have done anything unusual in the way of making sponge of an exceptionally high quality.

Range of alloys about same

Titanium alloys in the USSR appear to be about the same as those in the US. The Soviets have high strength alloys, and high temperature alloys of the aluminum-tin variety. They take pride in a weldable sheet alloy of 5 pct Al. They have aluminum-vanadium and aluminum-chrome alloys of various contents.

In fabrication, apparently they can forge, weld, and roll just as well as can be done in this country, and they seem to be aware of about the same types of problems as are encountered here.

A greater effort on titanium powder

There appears to be a greater effort on titanium powder metallurgy in the USSR than in the US. Dr. Timoshenko of the Central Scientific Research Institute for Ferrous Metals, does rather substantial research in powder metallurgy with about 30 people employed in this work.

They show a powder metallurgical ingot, 15 in. in diam, weighing 23 kg, made of 4 pct V and 0.3 pct Al; it was formed at 1400°C in 10^{-4} mm vacuum. There are some ingots and hammer forged products that have been formed in slabs at temperatures up to 1000°C, hot rolled into sheets, and further cold rolled into foil of about 0.003 in. thickness. They also can make wire down to 0.003 in. diam.

The Russians appear to be making suitable powder products by two techniques: one by blending vanadium, titanium, and aluminum powders, getting the titanium from titanium hydride. The sintered product is forged or rolled. They also have the technique of co-reducing a mixture of titanium dioxide, aluminum trioxide, and vanadium pentoxide. All are reduced by calcium hydride.

There may be a third powder metallurgy technique for titanium used in the USSR, an electrolytic process. This may be used only in the laboratory,

but they are very much concerned as to American success in producing titanium powder by electrolytic techniques.

They showed a 9 pct Sn alloy that was the result of powder metallurgy; so, apparently they are making some high temperature alloys by this technique. Again, this was in a laboratory, and we do not know how close it is to production.

Turbine blades inspected

At the Central Scientific Research Institute for Ferrous Metals there were some 20 steam turbine compressor blades, supposedly made from pure titanium, on display. They were pressed hydrostatically, sintered at 1400°C under vacuum, and then forged in open forging dies. The size of these blades were 2-¾ in. wide by 8 in. long. The hardness for these blades was supposed to be about 180 Brinell. They also had some alloyed blades that had hardness of 210 Brinell. Composition was 0.105 pct H, 0.5 pct O, and 0.5 pct N.

Tensile strengths ranged up to 85,000 psi on the pure titanium and 140,000 for the alloy blades. The elongation of the pure titanium was 30 pct, and the reduction in area was 25 pct. In the case of the alloy, the elongation was 15 pct, and the reduction in area was 10 pct.

Melting techniques employed

In one research laboratory titanium was being melted in a half dozen different ways. For instance, there was an induction furnace using a water-cooled, copper hearth. The copper hearth was very shallow, and the high frequency induction unit apparently was designed so it would concentrate its heat in the titanium portion on the top of the hearth. This was at the Polytechnic Institute of Leningrad.

Cast titanium was also seen. The largest piece was something on the order of 15 lb. It was done by skull melting in the laboratory. How much larger castings could be made than this particular item is not known.

Titanium: Opinions and Ideas

Highlights of the panel discussion at this year's Titanium Symposium.

BUDGET cutbacks and earth satellites have not come about without effects in the titanium industry, and these matters were prominent in discussions at the AIME's sixth annual Titanium Symposium, held in Chicago last November, coincident with The Metallurgical Society's annual Fall Meeting. After the prepared talks, a distinguished panel took over to thrash out some of the problems facing the industry. The session was under the Chairmanship of L. S. Busch of Mallory-Sharon Metals, and N. E. Promisel, Dept. of the Navy, served as moderator. Participating were J. L. Waisman, Douglas Aircraft; A. Hurlich, Convair Div. of General Dynamics; G. J. Wile, General Electric; W. H. Sharp, Pratt & Whitney Div. of United Aircraft; R. T. Jameson, U. S. Air Force; S. V. Arnold, Watertown Arsenal; W. Lusby, du Pont; W. L. Finlay, Rem-Cru Titanium; W. W. Minkler, Titanium Metals; T. E. Perry, Republic Steel; and C. B. Voldrich, Battelle Memorial Institute. Below is an extract of the highlights of this discussion.

. . . On quality control

Mr. Waisman: " . . . Quality control needs to be improved . . . There are a number of fairly minor but important technological problems that have to be licked. We need to get into the strength range of something like 180,000 to 200,000 psi to be competitive on a strength basis with many of the steel alloys that are being used, and in order to have wide-scale use of titanium, it will be very helpful, if not necessary, that the high strength alloys be weldable as well as heat-treatable.

"A lot of work is being done on airframes where titanium is being used with aluminum. There is a high chemical potential difference between the two materials, and although the titanium doesn't corrode, suitable precautions have to be taken to see that aluminum doesn't corrode when placed in contact with it."

. . . On missile applications

Mr. Hurlich: " . . . We feel that weldability is an extremely essential requirement. Unless a material is weldable by practical production methods, it is not particularly suitable for many missile applications. So, with the emphasis on weldability, we are willing to sacrifice some of the high strength and will be very content with materials on the order of 100,000 to 130,000 yield strength, provided they are weldable and can develop a very high proportion of their strength through welded joints, preferably as welded, or possibly after heat treatment.

"Weldability should be emphasized, because in the titanium picture, it is apparently rearing its ugly head at a relatively late date. In so far as various applications of titanium in missiles are concerned, the high price of titanium dictates its use in areas where it will do a job better than any competitive engineering material, and there *are* such applications, among them being high pressure vessels. Titanium does offer some unique advantages in this area, and considerable effort is being devoted to its development. Here, we insist upon a high order of weldability and good ductility of the joints to avoid fracturing. In so far as sheet materials are concerned, these too, must be fabricable by welding and a good degree of formability is desired.

"There are many low temperature applications of importance and we require alloys to retain a high order of ductility several hundred degrees below zero in the welded condition. So, consequently, the prime points that I wish to express are the necessity for weldability, the necessity for ductility in welded joints, particularly at low temperatures, and I think that considerable effort might very well be directed by those people who are in the process of developing

and manufacturing titanium to attempt to meet these requirements."

. . . On temperature limitations

Mr. Wile: " . . . The unfortunate situation as we see it, is that the strength of titanium alloys today is quite limited. We don't see much application of current titanium alloys at temperatures beyond approximately 930°F. We are anxious to use the new titanium alloys, but they are extremely difficult to apply. You have to pay close attention to timing; your engine objectives are scheduled pretty far in advance, and you have to make material selections very early in the game.

" . . . Our engines specific weights are not only going down, but our temperatures are going up. We are flying the machines at faster speeds. Just a few years ago we were talking about speeds of mach 1 to mach 5. And you probably all know at mach 3, the temperature is 600°; so, at mach 4, we are talking about temperatures at the range of 1200°. Once you hit mach 3, it means a large increase in temperature, so we are slowly pushing titanium out of the engine. It doesn't appear that we will be using any titanium at all, if this future trend is to be continued.

" . . . What you have to really do is take a strength weight function and integrate over the entire volume of the part, because the stress will vary on the part. Large volumes of the parts may not be stressed at all, and a weak titanium, even at those temperatures, will result in a very large weight saving, and this to me is one of the real inherent advantages of titanium alloys. Titanium dead weight is going to be lighter than any kind of steel dead weight."

. . . On welding titanium

Mr. Sharp: "Welding in the open means welding with a good shield around the welding head and a trailing cup to protect the weld from oxidation while the weld is still in the molten, semi-molten, or solid state.

" . . . It is most important to use a raw material which is low in oxygen, and it happens that it is much easier to draw a welding mark on low oxygen alloys. On the higher oxygen, we are in a fortunate position; we limit our oxygen in alloy welds to about 0.2 pct. If the oxygen content gets higher, the welds become bent and brittle, and of course, this can be quite serious, particularly in welds where a great amount of strain is developed. The oxygen limit for welding of other alloys, such as the alpha-beta alloys, is somewhat less. For our alpha alloys the limit is probably about 108 to 110 ppm. I don't happen to know about allowable oxygen in the stable beta alloys at the present time. We weld titanium containing a fair amount of oxygen in the open without too much trouble. Here again, we give ourselves the benefit of using a high purity titanium filter rod.

" . . . One thing that should be borne in mind in welding titanium alloys is that unlike aluminum alloys, titanium alloys develop high yield strengths. This means that residual stresses in titanium alloy welds can be higher—not necessarily so, but can be. This makes it important to get rid of residual stresses in the weld as soon as possible. Of course, this can be done by a stress relieve treatment in the range of 1000°, or as high as 1300°.

"We are going into a new area of welding at this time. A great many of these alloys that heretofore have been considered not weldable can be welded. Techniques have to be refined; we have to select the filler materials very carefully, and we will probably go in the direction of alloying them down to the filler method."

. . . On new rolling processes

Mr. Perry: ". . . Continuous cold rolling mills are a fascinating field for titanium. It is a little surprising this late in the game that a new field is just opening up and is so fertile with the challenge of new ideas and new techniques. Also, there is the ability to make optimum use of new and possibly modified cold mill equipment, of which we have a greater variety than we do of hot handling equipment.

"It would have been very surprising to know a year ago that many of the alpha beta type high strength alloys *do* have sufficient cold malleability to sufficiently produce materials on cold mills and to extremely light gages. The production of alloys on the cold mills is still in the experimental and evaluation stages. Mechanically, it is physically possible to produce uniform gage, flat and consistent. The biggest problem today is the directionality of a given alloy or a family of alloys. How great this is, and in what gage and after what previous thermal production treatment, we are just beginning to determine. We had rolled, for example, high strength alpha-beta type titanium alloys down to 0.001 gage. We currently have two alpha-beta type alloys coming through experimentally at intermediate gages, and are proceeding to commercial development of this on a much larger scale. We are extremely encouraged by what we have seen so far and hope the problems directionality can be worked out and minimized."

Extract of remarks by I. I. Kornilov of the Baikov Institute of Metallurgy, Moscow.

The general line of investigation in our laboratory is the chemical interaction of metallic elements. Thermal analysis, formation of solid solutions, metallic compounds, crystal structures, phase diagrams, phase transformations, and the influence of composition and structure on the properties of alloys, are all questions which we have studied. The objects of our investigations are 1) iron, nickel, and cobalt; 2) metals of chromium group; and 3) titanium.

The classification of binary titanium systems and solid solubility of elements in titanium are published in USSR and also in the German language (in 1956), as my report in the 3rd International Congress of Light Metals in Austria (Leoben). Our studies on phase diagrams of titanium systems have been published in the Soviet Union. We have spent time on the study of policomponent titanium systems from the point of view of the geometrical presentation of results of reaction and equilibrium in 5-6-8 component systems. On these subjects we also have some published works.

For the investigation of the strength of metals and alloys at high temperature, we have an original method: the use of centrifugal force for slow deformation (creep) and rupture measurements. This method is also used for studying high temperature strength of titanium alloys.

In conclusion, I hope that our scientific work, together with analogous work on titanium being done in the USA, England, France, Germany, Japan, and other countries, will open the door for extensive use of it for peaceful purposes.

by F. J. Krenzke, J. W. Hays, and D. L. Spell

HIGH PURITY ELECTROLYTIC MAGNESIUM

Major impurities can and are being controlled to low levels to meet the demand for high purity magnesium as a reducing agent for reactor metals.

DURING 1956, the amount of magnesium consumed in the U.S. as a chemical reagent roughly equalled the amount used for structural purposes. The bulk of 20,000 tons used as a reducing agent went into the production of titanium, with smaller amounts being used in the production of zirconium, beryllium, and uranium.

Impurities in magnesium may be carried into these metals and adversely affect their critical properties. Boron and cadmium are examples of such impurities, and their tolerance level in magnesium is measured in tenths of a part per million. It became necessary, therefore, to develop a much more detailed picture of the minor impurities in magnesium than had been necessary heretofore.

Since the electrolytic magnesium plants on the Texas Gulf Coast are the country's principal source of magnesium, this paper deals only with metal from them. These plants derive their magnesium ion from sea water and reduce it to metal by electrolysis of the molten chloride.[1-8] Magnesium produced by this method is remarkably pure. It is normally sold as pig or ingot under ASTM Specification B-92 which limits total impurities to 0.2 pct. Such material readily meets purity requirements for structural applications.

Impurities in commercial magnesium

Tables I, II, and III are the results of studies initiated for the purpose of developing a much more detailed knowledge of this impurity content. Table I presents the average concentration of six elements which are checked spectrometrically on a routine basis and for which large numbers of analyses are available. It is apparent that iron and manganese make up the bulk of impurities in this group.

Table II presents the average concentration of fourteen elements which have assumed sufficient importance in some proposed chemical application to warrant special study. Information on such elements as lead and tin was readily obtained. On the other hand, results on boron and oxygen represent months of effort in development of analytical methods of sufficient precision to give reliable results in the ranges required.

The case of oxygen analysis is of interest. Although several methods are available, the most reliable, though most tedious, consists of subliming a substantial quantity of magnesium and analyzing the unsublimed residue for magnesium oxide. Results of such analyses showed variation in the range of 0.002 to 0.02 pct O_2 until a series of samples of known and decreasing ratio of surface area to weight was carefully run. The results of this work showed that surface contamination accounted for the variations and that the oxide content of the metal was approximately 0.002 pct.

Table III lists elements which are below limits of analytical methods readily available. Except for the rare earths, for which more sensitive detecting methods are under study, these elements have not been of interest below the indicated levels.

Eight elements (Ga, Re, Se, Ta, Te, Th, U, and Y) are estimated to be below 0.003 pct, and sixteen (Au, Ge, Hg, In, Ir, Cb, Os, Pd, Pt, Rh, Ru, Sb, Sc, Tl, V, and Zr) below 0.001 pct. These estimates are

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Dow's Freeport, Texas, plant, where primary magnesium is produced.

Table I. Impurity Content of Primary Dow Magnesium—Elements Checked on routine Basis

Element	Avg Analysis, Pct
Mn	0.06
Fe	0.029
Cu	0.0014
Ni	<0.0005
Al	0.005
Si	0.0015
Total	0.0974

based upon analyses of process liquors from which the magnesium chloride cell feed is prepared. Actual concentration of these elements in primary magnesium is very likely substantially below the indicated levels.

Five approaches to impurity reduction problem

It is apparent from these tables that, on the average, primary magnesium contains less than 0.13 pct impurities of any significance and that 0.09 pct is made up of manganese and iron. The problem, then, of furnishing a high purity metal resolved itself into reducing the amount of these elements. In addition, where particular applications required extremely low concentrations of certain elements, these elements had to be studied and means for controlling them developed. Boron and aluminum fell into this category.

Five approaches to the problem of reducing impurity content were considered. These were: 1) distillation of magnesium metal; 2) chemical treatment of molten metal; 3) batch selection; 4) chemical treatment of process liquors; and 5) changes in materials of construction of process equipment.

Distillation is capable of producing material of very low impurity content in a single operation, but it is a costly process. Simpler methods were considered more feasible, because the major portion of impurities consist of only a few elements.

Table II. Impurity Content of Primary Dow Magnesium—Elements Checked by Special Analysis

Element	Avg Analysis, Pct	No. of Samples
Pb	0.0007	100
Sn	<0.0001	50
B	0.00004	100
Ca	0.0014	50
K	0.0013	30
Na	0.0017	30
Zn	0.003	50
C	0.0046	15
Cl-	0.0018	30
H_2	0.006	13
N_2	0.0025	70
O_2	0.0022	30
F	0.0002	30
S	0.0005	20
Total	0.0265	

Table III. Impurity Content of Primary Dow Magnesium—Elements Below Limit of Detection

Element	Detection Limit, Pct	No. of Analyses
As	<0.00002	2
Ba	<0.0001	13
Be	<0.0001	25
Bi	<0.0010	13
Cd	<0.00002	25
Cs	<0.0010	10
Cr	<0.0001	5
Co	<0.0010	13
Hf	<0.0002	5
Li	<0.0005	13
Mo	<0.0001	10
Rare Earths	<0.0100	13
Rb	<0.0005	13
Ag	<0.0001	13
Sr	<0.0001	13
Ti	<0.0010	50
W	<0.0001	10

Chemical treatment of molten metal: Since steel cathodes are used in the electrolytic cells, the metal removed from the cells is effectively saturated with iron at about 0.03 pct. Removal of the iron must, therefore, be accomplished by chemical treatment

of the molten metal. In general, this consists of reacting a part of the magnesium with a chemical, usually a halide. An insoluble metallic constituent is generated in the molten magnesium. As this settles, it carries with it most of the iron. The procedure has the advantage that it can be carried out in simple crucible furnaces.

A number of materials may be used to accomplish this end. Commercial fluxes are available which contain zirconium or manganese chlorides. Again, titanium tetrachloride may be used as described in U. S. Patent 2,779,672. The choice of agent depends upon the end use to which the magnesium will be put, since each of these agents leaves some residual impurity.

Batch selection depends upon process variances. When the impurity level normally occurring in the magnesium is close to that required for a given use, it is possible to select only the material at the lower levels of the range of occurrence. Costs for this method may be low or high, depending upon complexity and frequency of analysis and cost of segregating batches of metal.

Chemical treatment of process liquors is one of the simpler procedures available. It usually consists of precipitating a given impurity from aqueous magnesium chloride liquors followed by a filtration step. It has the disadvantage of being applied in an early processing stage, thus offering opportunity for impurity pick-up during later processing.

Changes in materials of construction of process equipment may be quite effective. An example of this is control of nickel. Over a period of time it was noted that the level of nickel in the magnesium was slowly increasing and occasional batches showed nickel above the 0.001 pct specification for primary magnesium. The difficulty was traced to a plant practice which consisted of running a few beads of 18-8 stainless weld along the edge of the metal collection well on the cell to provide a hard wearing surface for sludging tools. A high carbon-manganese steel was substituted with a resulting improvement in nickel level.

Four methods adopted

In actual practice, all of the last four methods of reducing impurity content are used either alone or in combination with each other. The system has offered considerable flexibility to the plant operator by permitting him to use only those steps required to furnish material for a given market. The result has been establishment of four grades of high purity electrolytic magnesium which cover the field of demand as it has appeared to date. Specifications for these grades are given in Table IV. Primary magnesium is included for comparison.

Where a need exists for an impurity specification very close to process capabilities, uncontrolled process changes, sampling limitations, and analytical procedure error must be recognized, and statistical techniques employed to adequately describe the impurity content of the product. A typical example may be illustrated in the control of aluminum below 0.002 pct in special grades of magnesium. The process average of aluminum in regular grades of magnesium is more than twice this level. The first step involves obtaining a lower average aluminum content. Aluminum is picked up from the cell refractories. A study was made of this factor which showed that the aluminum pick-up decreased as porosity of refractories and cell temperature decreased. Installation of suitable refractories and control of cell temperature made possible the necessary reduction in average aluminum content. Knowledge of variances due to sample limitations, uncontrollable process changes and analytical error then enabled the producer to select specification grade metal with some 95 pct assurance that the sampled metal fell within the specified tolerance level. Similar considerations apply to other variables such as iron and manganese.

Extensive analytical program required

High purity electrolytic magnesium production involves an extensive analytical program with dependable accuracy and precision. The methods of analysis can be divided into the following categories: 1.) routine spectrometric methods to determine metallic impurities within the usual detection limits; 2.) sensitive chemical and spectrometric methods to determine trace metallic impurities beyond the scope of routine methods; 3.) special methods, chemical and spectrometric, to determine non-metallics; and 4.) chemical and spectrographic methods used as back-up and checks on the routine methods.

The combination of process changes, equipment modification, improved analytical methods, and statistical techniques has thus provided means for meeting the requirement of a large new market in an economical manner. Should substantial new markets develop which demand different or more stringent specifications, it is possible that the approaches described may be further extended and refined.

References

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[2] C. M. Shigley: Metals Technology, vol. 12, April 1945.

[3] R. M. Hunter: Electrochemistry of the Dow Magnesium Process, *Trans.*, Electrochemical Society, 1944, vol. 86.

Table IV. Specifications for Primary and High Purity Grades of Dow Electrolytic Magnesium

Grade	Al, Pct	B, Pct	Ca, Pct	Cu, Pct	Fe, Pct	Mn, Pct	Ni, Pct	Pb, Pct	Si, Pct	Sn, Pct	Other Metallics	
											Each, Pct	Total, Pct
Primary[1]				0.02		0.15	0.001	0.01		0.01	0.05	
Mg 2				0.02	0.05	0.01	0.001	0.01		0.01	0.05	0.10
Mg 3	0.004		0.003	0.005	0.03	0.01	0.001	0.01	0.005	0.005	0.01	0.08
Mg 4	0.002	0.00007 [3]	0.003	0.004	0.03	0.004	0.001	0.005	0.005	0.005	0.01	0.07
Mg 5[2]				0.003	0.003	0.004	0.001	0.005	0.005	0.005	0.01	0.05

[1] Total of all impurities 0.2 pct max.; 99.8 pct Mg by difference.
[2] Tentative specification.
[3] Limited data on boron content indicates less than 0.00003 pct.

by Arthur F. Johnson

METALLURGICAL PROBLEMS AFFECTING THE ECONOMICS OF ALUMINUM PRODUCTION

How much of the growth of the aluminum industry is due to technological improvements made by metallurgical engineers? How much are new designs of reduction furnaces and plants, as well as operational techniques, contributing to the security of invested capital and its rapid return?

THE metallurgical engineer has improved and can continue to improve the return on investment in aluminum plant in two ways: first by devising a design that costs less per annual pound of aluminum produced, and second by operating at a lower cost per pound of aluminum produced.

The first pots used by Hall in the 1890's and up to the 1920's had anode electrodes only a few inches in diameter and current densities of 40 amps or more per sq in. Hall's earliest pots took only a couple of thousand amperes and had to be externally heated with gas burners to keep the cryolite molten. As larger pots were built, there was less radiating surface per unit volume of molten cryolite and metal, and external heating was no longer required. Thus, the whole history of improvement of efficiencies in the aluminum industry has been one of using lower and lower current densities in larger amperage furnaces. The larger conducting area has permitted a decrease in operating voltage and, hence, lower kw-hr per lb.

In an effort to lower unit costs, reduction furnace size has been increased from 32,000 amps to as high as 120,000 amps, and the number of furnaces per potline increased from 128 to 170. Present electrodes range up to 6 x 35 ft in the larger soderberg furnaces, and up to 20 x 30 in. in the prebaked electrode designs where from 20 to 30 electrodes are used. The long potlines have been a success, but the operation of the large pots has been fraught with difficulties.

Itemized operating costs, such as are shown in Table I, serve to emphasize areas where the greatest economies can be made. While power and alumina costs are considerable, labor costs, together with direct and indirect overhead, as well as the capital costs necessary for plant construction—estimated to total 6¢ per lb of aluminum today—easily amount to the largest single cost item, 10¢ per lb of output.

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Lowering costs by increasing output

One solution to the problem of lower aluminum reduction costs is to increase production from existing or modified equipment. Overhead, labor, and capital costs will be less in proportion as plant production is increased.

Suppose, for the sake of magnifying the problems involved, one increased the capacity of a reduction plant by 25 pct and, thereby, attempted to reduce overhead and labor costs from 10¢ to 8¢ per lb. Part of the financial gain will be lost by increased power consumption.

From Table II, 0.9 v is used up by resistance losses external to the electrolyte. If the current were to be raised to 125 pct of the original, the voltage lost external to the electrolyte would rise to 1.1 volts and the dissipation of the RI^2 loss might become a major problem. To the extent that the voltage losses were due to metal to metal contact drops, the rise would be greater than in proportion to the current rise due to non-conductive metal oxides forming at hot joints. To the extent that the voltage losses were due to conduction through carbon, they would be slightly less than in proportion to the current rise, because of the decreasing resistance of carbon with temperature. The heat loss due to use of a current 125 pct of the original would be 156 pct of the initial heat loss. This heat, where external to the furnace, is lost by radiation and conduction.

Bus bar installations: A great many reduction plant installations have been made where the bus was installed in closed trenches under the floor level without any planned ventilation. Buses have been made in one piece, rather than in several leaves, because they are cheaper in one piece. There are many pot rooms that are limited as to metal production capacity by the carrying capacity of the

bus. The bus bar may constitute a production bottleneck of the entire plant.

Modern pot room bus bar installations are made of aluminum. They are well ventilated, and they have nearly all joints welded, including joints between copper or aluminum flexibles and aluminum bus. A clamped or bolted joint of aluminum to aluminum, or aluminum to iron, should never be used with heavy current, because of the tendency of aluminum to oxidize and insulate itself. Even aluminum to copper bolted connections are not recommended, but only copper to copper which can be obtained with aluminum bus bars by electric welding copper strips to aluminum at the place where the bolted or clamped contact is to be used.

Collector bars: If the amperage were to be increased 25 pct on a potline, a second point of weakness that might develop would be failure of collector bars and sides of the pot, evidenced by collector bars or sides first becoming red and then leaking metal through the collector bar hole or through a hole eaten in the side of the pot by molten aluminum or cryolite. In present designs, the iron collector bar current-density usually runs about 200 amps per sq in. In early Hall designs, it ran up to 330 amps, but the old Hall designs carried considerable current horizontally through the pot lining directly to the side of the 1½-in. thick steel side of the pot. This acted as a bus to carry the current to the ends of the pot nearest the main bus line. From the standpoint of reducing magnetic circulation, this old Hall design was faulty, because it caused horizontal flow of current in the metal cathode instead of essentially all vertical flow, as sought in present design and operation. Any pot design that employs great width is apt to be faulty, because of the flow of current horizontally in the metal pad from the middle of the pot to the sides.

Dissipation of heat: Table III shows the heat and power balance for an 80,000 amps prebaked cell. When amperage is increased, more heat must be dissipated from the pot shell.

In the soderberg designs, the top of the pot shell must be at or near, the working floor level, for convenient access by the workmen to all sides of the pot. Consequently, the pot shell itself is below the floor level and not subject to ventilation unless forced ventilation with fans and underground vents, or by installation of a basement for ventilation. While such layouts are expensive, they have been used with soderberg furnaces of 65,000 amps or more. Certainly, if it is contemplated increasing the load 125 pct of rated capacity in any design, then means of dissipated 156 pct as much heat must be provided or the bottom or sides of the pot will burn out. In computing the economics of using fans, one must consider the aluminum lost by not using the power for reduction which is used to drive the fans.

Heat Insulation: The heat transferred to the shell from the bath itself can be materially lessened by use of good insulation between the carbon pot lining and the shell. The fundamental problem here lies in the fact that good insulators are porous materials and these absorb cryolite after some months and lose from 50 to 80 pct of the insulation value in proportion to porosity. Hence, newly lined furnaces are well insulated, and furnaces with old linings poorly insulated.

The answer to this problem is clearly one of making an impervious partition between the pot lining and the pot insulation. The material most resistant to metal and to bath attack is cast iron plate which overlap and blanket the insulation in the furnace bottom and also serve as collector plates for cathode current. They may be reinforced with hot-rolled steel rods, cast into the iron and serve as collector bars. A satisfactory side insulation is still in the process of solution. A graphitic cast-iron shield—to protect the heat insulation—made even more resistant to metal and bath attack by coatings of certain nitrides, carbides, or borides is suggested.

Table I. Example of Estimated Aluminum Reduction Operating Cost on 60,000 Ton Per Year Plant Using Power at Cost Comparable to That From TVA

	¢ Per Lb
Power: 9 Kw-hr @ 4.25 mills per Kw-hr	3.83
Alumina: 1.91 lb @ 3.7¢ per lb (includes plant-amortization, interest, and profit)	7.07
Cryolite and aluminum fluoride: 0.05 lb @ 15¢ per lb	0.75
Labor: 0.008 man-hr per lb @ $3.00 per hr (including overhead)	2.40
Repair & maintenance material: (including potlinings)	1.00
Electrodes: 0.6 lb @ 2.5¢ per lb	1.50
Miscellaneous plant costs	0.95
Indirect overhead	0.50
Total operating costs	18.00
Amortization, interest, and profit	6.00
Freight to market	1.00
Delivered price of aluminum pig	25.00

Lowering costs by decreasing input

The other solution to the overall problem of reducing costs of aluminum reduction is by using less of the components. To assist in selecting the important cost components in aluminum reduction, reference may be made to Table IV, the material and power components of making aluminum. While alumina was shown in Table I to be an important cost factor, there is no chance of using less alumina, excepting by reduction of the dust loss that is represented by the difference between the actual pounds of alumina consumed per lb of aluminum—1.91 to 1.95—compared to the theoretical use factor of 1.89. However, the actual use of other items is quite high compared with the theoretical amounts required. Electrical power is particularly noteworthy; it is closely related to ampere efficiency which in turn is tied in with the evolution of carbon dioxide in the reduction cell. Much work is currently being done by metallurgists in this regard.

CO_2 evolution and ampere efficiency

Oxygen formed on the anode carbon in the aluminum reduction cell, instantaneously burns to carbon dioxide. At 100 pct efficiency, 1000 amps produce each 24-hr day, 17.746 lb of Al and 21.689 lb of CO_2, equivalent to about 800 cu ft at 960°C. At a current density of 5 amps per sq in. of anode, and an anode-cathode spacing of 1.5 in., the gas generated is sufficient to fill a volume approximately equal to that between the anode and cathode three times every minute. Of course, the gas does not accumulate under the anode, but it is evolved in a steady steam or in periodic gulps of bubbles. In its passage, some of the carbon dioxide encounters a metallic mist of aluminum that rises from the molten cathode and remains suspended in the cryolite bath. This portion is reduced to carbon monoxide at the expense of the aluminum mist, which is re-oxidized to alumina, thereby reducing ampere efficiency. No change in gas volume is involved in this reaction.

Normally, ampere efficiency ranges from 85 to 90 pct. With 85 pct efficiency there will be about 70

pct CO_2—100 minus double the efficiency loss is the pct CO_2 in the anodic gases. This would be expected from the following reactions:

$$2\ Al_2O_3 + 3\ C = 4\ Al + 3\ CO_2 \quad \text{(electrolytic reduction)}$$
$$3\ CO_2 + 2\ Al = 3\ CO + Al_2O_3 \quad \text{(reoxidation of half the metal reduced)}$$

In other words, current efficiency in percent equals: [Pct CO_2 in anode gas + 100] ÷ 2.

In the past, some metallurgists seemed to believe that part of the carbon dioxide was reduced by the carbon electrode, but the present view is that aluminum performs practically all the reduction of the carbon dioxide. This might be expected from the heat of reaction of 127 kg-cal per mol CO_2 produced in the exothermic reduction of carbon dioxide with aluminum, compared with 39 kg-cal consumed in the endothermic reduction of carbon dioxide with carbon.

Anode-cathode distance: The production of aluminum fog in the cryolite bath increases rapidly with higher bath alkalinity and temperatures above the normal bath operating temperatures of 940° to 980°C. Unevenness in anode-cathode distance brings the anode gases into contact with the metal fog at points of close contact, where the temperature is higher due to greater current density, and increases even more by the burning of aluminum fog by carbon dioxide.

In a 100,000 amp pot, the anode area may be 130 sq ft, separated from the molten aluminum cathode by only 1.5 in. To further complicate the problem, the molten aluminum cathode at 960°C has a density of about 2.3 compared to about 2.1 for cryolite; hence, the metal is buoyed up by the cryolite bath so that the effect of gravity on the metal is roughly one tenth what it would be in air. This magnifies by ten the relative effect of both magnetism and surface tension.

In recent years, particular attention has been given to this problem, but only after high amperage potlines failed time and again to give good results. For this reason great attention has been given to making all operating conditions uniform. Tapping is done daily, or every two days, so that there is less cyclic variation in cryolite bath level and temperature. Additions of paste to the soderberg electrodes is made in small amounts daily rather than once every week or two, so that cyclic variations in baking are minimized.

Various formulas have been published showing ampere efficiency to be a function of anode-cathode distance; however, it would appear that ampere efficiency is not just a function of anode-cathode distance, but rather a function of the effective distance between the carbon dioxide evolved from the anode and the metal mist layer above the cathode. This can be termed the CO_2-to-Al distance. The rate of gas formed at an anode can easily be calculated, but the rate of evolution depends not only on the distance the gas has to travel to reach the edge of the electrode, but also on bath viscosity, bath movement due to thermal and magnetic circulation, the effect of alkalinity and temperature of the bath insofar as they cause formation of metal fog, and the upward slope of the bottom face of the anode.

Channels naturally form in certain designs of soderberg electrodes that have horizontal pins, since the gas follows the pin holes. However, these do not represent the evenly spaced channels needed to effectively eliminate all large bubbles from the anode face.

Table II. Estimated Voltage Drops in a Modern Prebaked-Type Reduction Cell

	Volts
Electrolysis (decomposition plus polarization)	1.8
Anode effect	0.1
Pot lining drop	0.4
Carbon electrode and clamp drop	0.35
External losses (buses and joints)	0.15
Resistance of electrolyte	1.9
Total	4.7

Narrow electrodes suggested: The simplest means of removing carbon dioxide gas as rapidly as it is formed seems to be the use of narrow electrodes or bundles of narrow electrodes joined together at the top with a solid carbon top or by cast iron which serves both as a means of electrical connection to the anode and as a means of joining and supporting the electrodes. To prevent surface oxidation of the electrode bundles, a cap of ⅜-in. thick aluminum may be cast over the bundle in the carbon rodding room. Such a cap can reduce net carbon consumption to 0.4 lb per lb of aluminum. It is now rather common practice in some European plants.

Various investigators have related ampere efficiency to an inverse function of anode current density and anode-cathode working distance. However, ampere efficiency must also be related to anode width. It can be demonstrated experimentally that aluminum melted in a crucible under a molten cryolite flux will oxidize at a rate proportional to the horizontal area exposed to the cryolite, presumably due to solution in the cryolite of aluminum or atmospheric oxygen or both. The same condition exists in pot room operation, and it can be assumed that with lower current densities, the cathode pool is actually burning up faster; therefore, a higher CO_2-to-Al distance is necessary to maintain ampere efficiency.

Current densities. To better understand the effect of carbon dioxide, it would be helpful to measure its velocity of travel through the molten bath and the average size of bubble formed under different conditions, because it is conceivable that at low current densities, the gas bubbles might, under certain conditions, grow to larger sizes and thus cause just as much reoxidation as at much higher current densities.

To save investment in furnaces, it would be desirable to run at high current densities, if at the same time, pot voltage could be held down by using a low anode-cathode distance. At present, this is not possible owing to the reoxidation of aluminum caused by faulty removal of carbon dioxide. The bad effects of the gas are three-fold: first, it crowds the

Table III. Estimated Heat & Power Balance on Prebaked-Type Reduction Cell
(Assume 80,000 Amp, 4.7 v, Ampere efficiency 86 pct)

Heat & Power Into Cell	Pct
Electrical (amp x v)	75
Heat produced by oxygen from Al_2O_3 electrolysis burning to CO_2 at anode	18
Heat produced by aluminum reoxidation (loss in ampere efficiency)	4
Heat produced by electrodes burning above surface of bath	3
	100
Heat & Power Out Of Cell	
Electric power for decomposition of aluminum	42
Heat lost by convection and radiation from sides, bottom and cover of cell	33
Heat lost in exhaust gases	20
Heat lost in hot aluminum and electrodes removed from cell	2
Losses in buses and contacts outside of cell	3
	100

electrolyte out of the anode-cathode space and so effectively increases the current density; second, it presses down into the metal fog burning it up; and third, it sets up a bath circulation that tends to drag this metal fog layer off the cathode up into the anode area where it burns up. The most obvious solution to the problem appears to be the use of narrow electrodes.

Effect of magnetic force on cathode metal pool

The problem of magnetic effects on the cathode pool is very close to the problem of carbon dioxide removal, because magnetism can cause poor ampere efficiency by displacing aluminum upward from a level pool until it contacts gas near the anode and is reoxidized. In the Hall process, as stated above, the cryolite electrolyte has a specific gravity of about 2.1 compared to 2.3 for the molten aluminum, so in effect the aluminum behaves like a liquid with a specific gravity of about one tenth that of aluminum.

A mechanical force is exerted on an electrical conductor carrying a current when in a magnetic field, tending to move the conductor perpendicularly with respect to both the conductor and the field. For example, the current in the horizontal anode bus above a pot makes a horizontal magnetic field component in the aluminum cathode pool beneath it. Current is also flowing vertically through the metal cathode pool. The interaction of the horizontal magnetic field and the vertical current causes the metal to heap up as much as an inch or more until the force of gravity balances the magnetic force. The metal tends to heap up in the direction towards which the anode bus current flows. When pots are arranged end to end and all the current enters the anode at one end of the pot, then metal tends to pile up at the end of the pot opposite to that where the current enters. But when the pots are arranged parallel to one another, and the anode bus enters from both ends of the pot, then the metal tends to pile up in the center. If there are areas of the pot where there is practically no horizontal component of magnetic force, or if there are wide strips of the metal cathode not covered by anode electrodes, then the metal, which is under magnetomotive force elsewhere, will seek these neutral areas.

The magnetic forces can be reduced by splitting the anode bus so that it enters from each end of the furnace. This has long been the practice with prebaked furnaces in the US which can be packed closely together in a pot room and worked alternately from each end by the potmen when they stir in alumina. In the case of the cathode bus, horizontal magnetic components in the cathode metal pad are avoided by making the elevation of cathode bus and metal pad correspond. Vertical magnetic components in the metal pad are not serious unless there are horizontal currents in the metal pad. Horizontal currents develop in wide furnaces since the electrical resistance sideways through the aluminum pad is obviously much less than it is through the smaller volume and higher resistance collector bar iron. It is for this reason that long furnaces having electrodes of the prebaked type, which can be adjusted for differences in metal elevation, are likely to be the most favored for furnaces of 100,000 amps or larger.

Table IV. Material and Power Components of Making Aluminum

	Range of Consumption Per Lb of Aluminum	
	Actual	Theoretical
Alumina (lb)	1.91 to 1.95	1.89
Carbon (baked lb)	0.40 to 0.60	0.33
Cryolite (lb)	0.03 to 0.06	0
Aluminum fluoride (lb)	0.01 to 0.02	0
Labor (man-hr)	0.008 to 0.010	?
Electric power (DC Kw-hr)	7.0 to 9.0	4

The problem of labor saving

As shown in Table IV, about 0.008 to 0.010 man hr per lb of Al are expended in an aluminum reduction plant. One of the greatest items of labor—20 to 25 pct of the reduction plant total—is spent in stirring alumina into the cryolite, an operation which is performed on each furnace every 2 to 4 hr. This job is essentially one of breaking the cryolite crust, stirring in the alumina and adding more alumina on to the top of the new crust which rapidly freezes when stirring is stopped. In the soderberg furnaces, the crust is broken between the electrode and the cold sides of the furnace and this operation requires a crow-bar or an air-operated jack hammer. On the prebaked furnaces, the problem is much more simple because the crust can be broken with the same bar that is used to stir the furnaces since the crust between the rows of prebaked electrodes is soft and easily broken. The aluminum industry in the US is spending $20 million to $25 millions annually for such labor in repetitive operation that doubtless could be mechanized either with an automatic breaking and stirring device on each furnace or a mobile device that breaks the crust and then stirs the bath, as it travels successively from furnace to furnace.

The stirring problem is certainly one capable of solution by machinery manufacturers. The aluminum reduction industry, with thousands of pots identical in size and requiring repetitive operations is a fertile field for automation.

Economy of investment

In order to make a good return on a given investment, low operating costs are needed.

In the aluminum reduction industry, low production costs have been sought by building larger and larger furnaces, while at the same time, reducing electrode current densities. As indicated in this article, there is reason to believe that lower current densities can no longer be the answer to lower costs. Any design of furnace that is larger and, hence more expensive per unit of production capacity, cannot compete in the present era of high captial cost. The success of the prebaked design of furnace used in most plants built for the US Government during World War II was due, not only to its efficiency of operation, but its economy and durability of construction.

The strong points of the design, known as the *Niagara* type were the clean-cut method of pot shell reenforcement with buckstays not attached to the shell, and deck plates held rigidly horizontal on the rim of the shell by multiple brackets. This shell reenforcement prevents distortion under the huge expansion pressures developed when bath freezes in cracks or absorbs in the cathode lining.

The close parallel spacing of the prebaked pots crosswise to the pot room building resulted in maximum aluminum production per unit of floor space.

by H. A. McDonald, J. E. Dore, and W. S. Peterson

HOW MOLTEN ALUMINUM AFFECTS PLASTIC REFRACTORIES

Resistance of a plastic refractory to molten aluminum is determined by the uncalcined clay content of the refractory and the phase changes it goes through on firing.

DURING the past several years, so-called plastic refractories have received considerable attention as construction materials for lining aluminum melting furnaces, both above and below the metal line. By definition, plastic refractories are a blend of ground fire-clay materials and an aggregate, suitable for ramming into place to form monolithic linings. Because of low cost and ease of installation, the major aluminum producers, and particularly the secondary metals companies, have built and operated furnaces lined with these materials.

Many types of plastic refractories and/or ramming mixtures ranging in alumina content from 40 to 90 pct have been tried. The performance of these materials below the metal line in aluminum melting furnaces has been erratic. Some installations have given excellent service, whereas the performance of others has been extremely poor. Under what appeared to be identical conditions, a given plastic refractory has shown both excellent and poor resistance to attack and penetration by molten aluminum alloys. Initial tests conducted at the laboratories of the Dept. of Metallurgical Research of Kaiser Aluminum gave similar erratic results.

Because of the anomalous results obtained in the field and in initial laboratory tests, a more comprehensive investigation of plastic refractories was undertaken.

Materials and test procedure for plastic refractory investigation

Three plastic refractory, alumina-silica compositions containing approximately 40, 60 and 85 pct Al_2O_3, respectively, were compounded. Table I presents chemical analyses of the three fired compositions and the bond clay. As is shown in Table II, the raw clay content of the various compositions decreased with increased alumina content. One lot of fire clay was used as the bond clay in all mixes.

Test pieces (9 x 2½ x 2½ in.) were rammed from each plastic composition. Samples of each composition were fired to 1600°, 1800° and 2000°F, and one 85 pct Al_2O_3 piece was fired to 2400°F. These firing temperatures generally cover the bake-out and operating temperatures used in aluminum melting furnaces.

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All of the test pieces were exposed to 7075 aluminum alloy at 1400°F for 168 hr, this alloy being used because of its rapid attack on refractory materials. A typical analysis of this alloy is 0.12 pct Si, 0.30 pct Fe, 1.60 pct Cu, 0.13 pct Mn, 2.60 pct Mg, 0.20 pct Cr, 5.90 pct Zn, and 0.01 pct Ti, the remainder being aluminum. The molten alloy and the refractory sample were contained in a No. 20 Tercod crucible.

The samples were suspended in crucibles containing molten 7075 Al alloy, and the crucibles were held in an electrically heated furnace, as shown in Fig. 1.

After completion of the holdings tests, penetration data were obtained by sectioning the test pieces with a diamond saw, parallel to the long dimension, and visually determining the extent of metal penetration into the refractory.

Tests indicate importance of clay content and firing temperature

The resuts of molten metal exposure on the plastic refractory pieces fired at various temperatures are summarized in Table III. It was found that the resistance of a plastic refractory to attack and penetration by molten aluminum is a function of the uncalcined clay content of the material, and the phase changes in the clay wrought by prefiring.

Firing Temperature: The temperature at which the various plastic refractory materials were fired prior to the molten metal exposure tests had a marked effect on the resistance of these materials to attack and penetration by the molten 7075 Al alloy. The plastic refractories that were prefired to 1600°F exhibited the maximum resistance to penetration. This resistance decreased slightly when a prefiring temperature of 1800°F was employed and then dropped sharply when a prefiring temperature of 2000°F was used. Fig. 2 shows the actual pieces tested.

Clay content: The uncalcined clay content of the plastic refractories also had a marked effect on the resistance of these same materials to attack and penetration by molten aluminum alloys. This can be seen by noting the clay contents listed in Fig. 2.

At prefiring temperatures below 1800°F, the 40 pct Al_2O_3 plastic refractory, i. e. the plastic with the highest raw clay content, exhibited the greatest resistance to attack and penetration. By contrast, the 85 pct Al_2O_3 material, i.e. the plastic with the lowest raw clay content, displayed the poorest resistance to attack and penetration. These results are contrary to those normally obtained with prefired brick, where

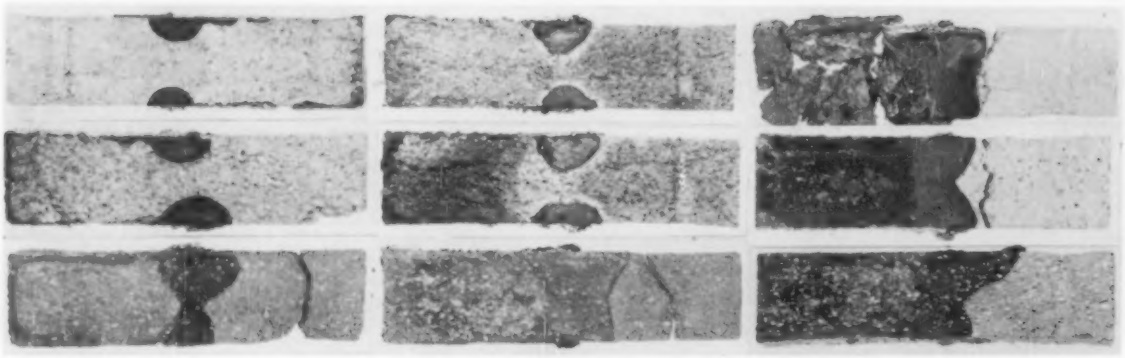

Fig. 1—Cross sections of three types of plastic refractory samples after exposure to 7075 Al Alloy at 1400°F for 168 hr. Top row: 40 pct Al_2O_3, 100 pct raw clay content; middle row: 60 pct Al_2O_3, 30 pct raw clay content; bottom row: 85 pct Al_2O_3, 15 pct raw clay content

resistance to attack and penetration increases with increasing alumina and decreasing silica.

The results of the molten metal exposure tests on the plastic refractory pieces fired to 2000°F were just the reverse of those obtained with the pieces fired at the lower temperatures: the 85 pct Al_2O_3 plastic showed the greatest resistance to attack and penetration. By contrast, the 40 pct Al_2O_3 material fired to 2000°F exhibited the least resistance to penetration. In addition, excessive metal penetration caused cracking and disintegration of the 40 and 60 pct Al_2O_3 materials, whereas this penetration did not appear to affect the structural stability of the 85 pct Al_2O_3 plastic.

Phase changes promoted by high firing temperatures

The increased attack by molten aluminum on these refractories, as both the firing temperature and the clay content is increased, suggests a possible relationship between the resistance of these materials and the well-known phase changes which occur in clay minerals during firing. To substantiate this premise, a series of test samples of pure bond clay was fabricated and fired to 1600°, 1800°, and 2000°F. These test samples were then held in contact with molten 7075 aluminum alloy.

The results of these molten metal exposure tests on the bond clay samples parallel those obtained with the plastic refractories. Cross-sections of the clay pieces are shown in Fig. 3. The same sharp decrease in resistance to attack and penetration occurred when the prefiring temperature was increased from 1800° to 2000°F.

X-ray diffraction analysis showed kaolinite to be the principal clay mineral present in the bond clay. This mineral undergoes a series of transformations when fired. At approximately 800°F the chemical water in the kaolinite crystal is driven off, leaving an amorphous material known as metakaolin. As the temperature is increased, the metakaolin becomes increasingly unstable until at approximately 1800°F, this material abruptly decomposes and subsequently forms alumina, mullite and free silica[1,2,3]. A diffraction pattern of the bond clay after calcination to 2000°F confirmed this transformation. Fig. 4 correlates these phase changes with prefiring temperature, resistance to attack and penetration, and the mechanical strength of the three plastics tested.

The good resistance of plastic refractories fired to less than 1800°F, then, is due to the presence of

Table I. Typical Chemical Compositions of Fired 40, 60, and 85 Pct Al_2O_3 Plastic Refractory Mixes and Bond Clay

Chemical Component	Plastic Refractory Mixes, Pct Al_2O_3			Composition of Bond Clay, Pct
	40 pct	60 Pct	85 Pct	
Al_2O_3	40.8	57.0	83.8	33.4
SiO_2	52.3	35.8	9.3	60.3
TiO_2	0.5	0.3	0.1	2.0
Fe_2O_3	3.3	3.7	2.9	1.9
CaO	1.2	1.0	2.8	1.0
MgO	0.7	1.0	0.8	0.4
Na_2O	0.3	0.5	0.2	0.3
K_2O	0.8	0.6	0.1	0.7
Total	99.9	99.9	100.0	100.0

Fig. 2—Cross sections of pure bond clay samples after exposure to 7075 aluminum alloy at 1400°F for 168 hr. Note the sharp decrease in resistance to metal attack and penetration in the clay sample pre-fired at 2000°F as compared to those pre-fired at 1600° and 1800°F.

metakaolin. This material is not readily wetted by molten aluminum and affords protection to the constituents of the plastic which are susceptible to attack. The poor resistance of plastic refractories fired above 1800°F can be attributed to the decomposition products of metakaolin (mullite and free silica). These materials are readily wetted, attacked and penetrated by molten aluminum alloys.

Problem: resistance to attack is best when strength is least

The two principal prerequisites of a refractory material for lining aluminum melting furnaces are: 1) Good resistance to attack and penetration by molten aluminum alloys; and 2) adequate mechanical strength to withstand the mechanical impact and abrasion which accompany placement of the charge in the furnace.

Unfortunately, conventional plastic refractories, as defined herein, cannot simultaneously meet both of these requirements. As shown in Fig. 4, the strength of conventional plastic refractories is relatively low when fired below 1800°F, where these materials possess their greatest resistance to attack and penetration. Thus, if the protective qualities of the metakaolin are to be utilized, low firing must be used. This will result in a furnace lining which is extremely susceptible to damage by impact and abrasion. If a firing temperature greatly in excess of 1800°F is used to develop adequate strength in a plastic lining, the metakaolin is destroyed and the lining no longer possesses good resistance to attack and penetration. In addition, firing temperatures considerably in excess of normal operating temperatures, 1300° to 1400°F, can damage the hearth of an aluminum melting furnace in other ways.

The mono-aluminum phosphate bonded materials may not have this strength limitation of conventional plastic refractories. Unfortunately, these materials were not commercially available at the time of this study.

Conclusion: plastic refractories unsatisfactory below the metal line

1) An explanation has been found for the anomalous results previously observed during the use of plastic alumina-silica refractories in contact with molten aluminum. The resistance of these plastic materials to attack and penetration by molten aluminum is related to the uncalcined clay content of the plastic and is particularly dependent upon the temperature to which the material is fired.

2) When initially fired to temperatures below 1800°F, plastic refractory materials show good resistance to attack and penetration by molten aluminum alloys. This resistance drops sharply when initial firing temperatures above 1800°F are employed.

3) The firing temperature sensitivity of plastic alumina-silica refractories is related to the phase or crystalline changes which take place when clay, principally kaolinite, is heated. Amorphous metakaolin, formed when kaolinite loses its chemical water, is not readily wetted by molten aluminum. Thus, this bonding material provides a protective layer over the aggregate particles and minimizes attack and penetration. Metakaolin decomposes at

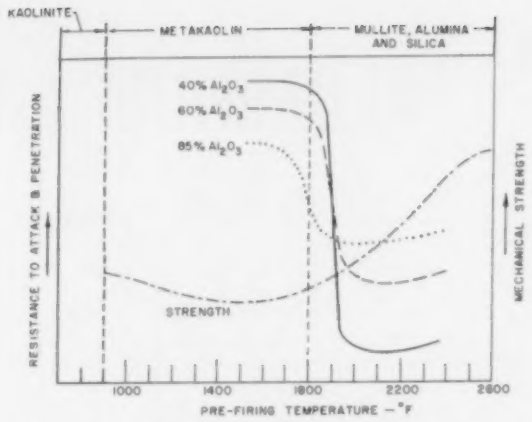

Fig. 3—Graphic correlation of the phase changes that the clay goes through with the properties exhibited by the three plastic refractories tested.

temperatures above 1800°F and the resulting products, mullite and free silica, are susceptible to attack.

4) Plastic refractories with a high clay content and low alumina content show the greatest resistance to penetration at firing temperatures below 1800°F. This resistance decreases with increasing alumina content and reduced clay content. This situation is reversed at firing temperatures above 1800°F where high alumina-low clay content plastics show the greatest resistance to penetration.

Unfortunately, the strength of conventional plastic refractories is at a minimum when firing temperatures below 1800°F are used. Consequently, these materials are not considered completely satisfactory for use below the metal line in aluminum melting furnaces.

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Table II. Batch Composition of Plastic Refractory Mixes

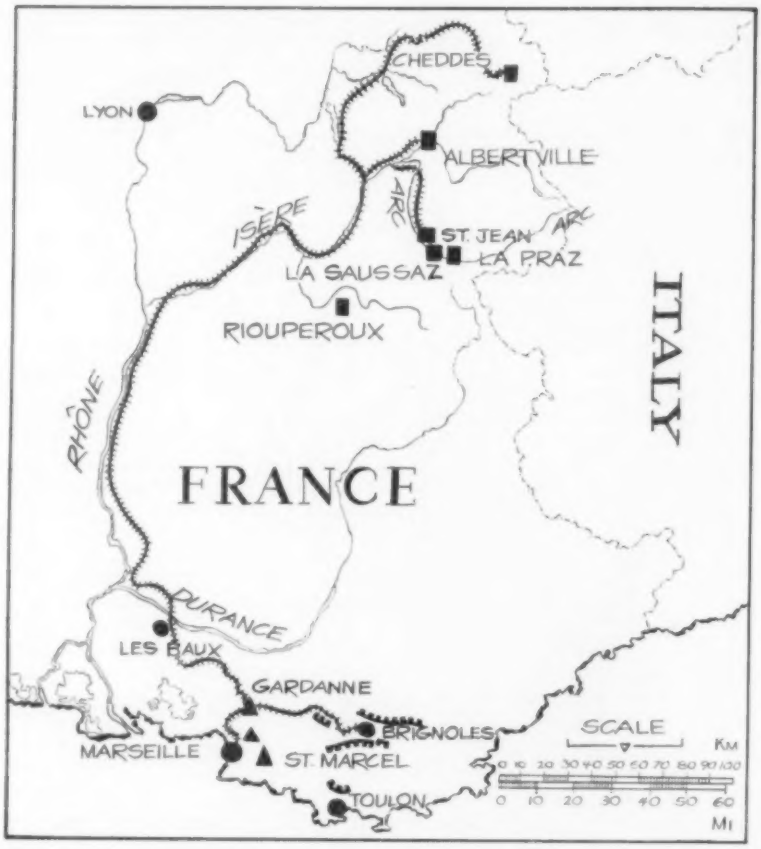
Plastic Refractory	Aggregate Content, Pct		Bond Clay Content, Pct	Total Raw Clay Content, Pct
	Calcined Material	Raw Flint Clay		
40 pct Al_2O_3		69.2	30.8	100.0
60 pct Al_2O_3	69.8		30.2	30.2
85 pct Al_2O_3	84.8		15.2	15.2

Table III. Results of Immersion Tests in Which Samples of Various Plastic Refractory Materials were Exposed to Molten 7075 Al Alloy at 1400°F for 168 Hr

Plastic Refractory Test Pieces	Firing Temperature, °F	Depth of Metal Penetration into Sample, In.	
		Max	Min
40 pct Al_2O_3	1600	0.6	None
	1800	0.9	Nil
	2000	Total	Total
60 pct Al_2O_3	1600	0.8	Nil
	1800	0.9	Nil
	2000	Total	0.6
85 pct Al_2O_3	1600	Total	0.15
	1800	Total	0.1
	2000	Total	0.3
	2400	Total	0.3

ALUMINUM AND FRANCE

If there is one metal that has been historically associated with France, it is aluminum. And today the country's aluminum producers are still leading the way toward more efficient output.
This is the first-hand story of a week's visit by JOURNAL OF METAL'S *managing editor to the bauxite mines, alumina plants, and aluminum reduction works of Pechiney, France's leader in aluminum.*



While bauxite was discovered at Les Baux, major exploration of the mineral has taken place in the region of Brignoles, to the east. With extraction at the rate of 1.6 million metric tons per year, these deposits are the basis of the aluminum industry of western Europe. Alumina plants are located largely in the region of Marseille, with the plant at Gardanne being the largest. Alumina is transported by rail some 250 miles to reduction works in the French Alps, largely centered in the valley of the Arc River. Squares indicate major reduction works, and triangles are for large alumina plants.

by F. Weston Starratt

LES Baux, a sleepy little village on the rocky cliffs overlooking the old Roman city of Arles in the coastal plain of southern France, is occasionally visited by tourists who view the ruins of the once fortified stronghold so rich in French history. But the village has still another claim to fame, for it was here in 1821 that a clay-like mineral, devoid of silica and high in alumina and ferric oxide was discovered; it was called *bauxite*. Little mining of bauxite has actually taken place in this area, for further to the east, in the Department of Var near the town of Brignoles, vast deposits of the same mineral, lying close to the surface, were discovered. These latter, the first commercially exploited bauxite deposits in the world, have long been the raw material basis, not only for the French, but also for the entire European aluminum industry.

France and aluminum

It can be said that, in many respects, France actually gave birth to aluminum, and much of the early experimenal work on the metal was done in France. In 1859 the newly formed chemical firm of Henry Merle & Co. extended its activities at Salindres to include production of aluminum by reduction of aluminum chlorides with metallic sodium, according to the method of Sainte-Claire Deville. This

was probably the only commercial aluminum plant in the world at that time. Merle's successor, A. R. Pechiney, continued chemical production of metallic aluminum until 1889; an output of 2960 kg was produced in that year. In the meantime Paul Heroult—as well as Hall in America—revolutionized aluminum by perfecting the process of electrolysis. The first French commercial production by the new technique was undertaken in 1889, and within a few years a score of aluminum reduction works, based on the Heroult process, were operating in France, Switzerland, Germany, and the United Kingdom.

First large-scale bauxite exploitation

To feed these new plants a race developed among the firms to stake out claims in the only known rich bauxite region of the day, the Department of Var in southern France. As a result of this *bauxite race* dating from 1890, claims were hurriedly staked out with little thought to the future. The area was criss-crossed with conflicting claims, resulting in confusion and a general subdivision of deposits into what, in many cases, later proved to be excessively small for economic extraction by modern methods. Some rationalization of these claims took place in later years, but the problem of subdividing the many small bauxite deposits of Var between the several operating companies plagues the industry to this day. There are now two French, one British, one Canadian, and one Swiss firm mining bauxite in the region.

Since the exploitation of bauxite started in this region, some 30 million metric tons have been extracted to supply the requirements of France, as well as Germany, the United Kingdom, Switzerland, and Austria. Prior to World War II, France led the world in bauxite output, but since then she has been surpassed by the United States, Jamaica, British Guiana, and Surinam, as well as the USSR and now Hungary.

The present rate of extraction in Var is about 1.3 million metric tons annually with mine output from other parts of southern France—largely the Department of Herault—amounting to 300,000 tons, so that the country's total bauxite production is on the order of 1.6 million metric tons. Requirements for the French aluminum industry amount to some 900,000 metric tons at present, leaving 700,000 tons for export.

Var deposits mined by underground techniques

In Var there are three distinct bauxite formations: one lying in the far north of the area, one just north of Brignoles, and one to the south of Brignoles, with the latter two being by far the most important. The mines in the Brignoles region operate a number of small deposits considerably broken-up by faulting caused by strong geological movements from the south. Most of the individual deposits do not have reserves of more than a few million tons.

At present, Var mining operations are underground, since surface deposits of low-silica bauxite have been exhausted, although the last of these closed down only recently. The mines operate to a maximum depth of 300 meters, but it is projected going to a depth of 600 meters in the future. For economic operation these mines must be capable of a minimum output of 200 to 300 tons per day. Average output is from 4 to 6 metric tons per shift per man, but several mines have achieved a production of 7 tons per shift per man, and through increased mechanization it is hoped to raise average output to this level.

But several factors prevent extensive mechanization of the mines. First, the deposits are small in extent and commonly divided between several operating firms. Second, the deposits are, in most cases, extensively broken by fault movement into small pockets of bauxite which are often difficult to locate in exploration work. Third, most of the mines have a serious seepage problem with considerable quantities of water percolating through the overlying porous dolomite layers. This forces a number of the mines to pump greater quantities of water than they are able to extract bauxite.

At Brignoles the surrounding hillsides are colored a vivid red for miles around; these are the bauxite deposits. The ores are largely the red type containing from 52 to 58 pct Al_2O_3 and 18 to 22 pct Fe_2O_3. The iron content is almost constant in these ores but the silica varies within a wide range at the expense of the alumina. The maximum economic silica content is 6 pct, and a lower silica content is highly desirable. The only bauxite encountered is the monohydrate in which the alumina is crystallized with one molecule of water. The water of crystallization plus moisture varies from 18 to 24 pct of the weight of the ore.

In the upper reaches of the deposits are found the white bauxite ores containing some 60 pct Al_2O_3, more silica—about 15 pct—and less iron—below 7 pct. Such ores are used largely for refractories. An intermediate grade is the grey bauxite which contains slightly more iron and less silica. These grey bauxites are ideal for abrasives.

Pechiney is largest producer

The largest firm operating in Var is the French aluminum and electrochemical firm, Pechiney, whose 1957 output of bauxite in France was 850,000 metric tons, with 620,000 tons being mined in Var with an underground working force of 520 men.

In general, the ore is removed from the underground workings by 10-ton skip hoists which follow the angle of the strike of the deposit. Trucks are commonly employed to haul the ore to a central railway collection point.

One bauxite mine near Brignoles is the Pelican which produces 600 tons per day from a maximum depth of 250 m. Water is a big problem at this mine, for 350 cu m must be pumped per hr.

For Pechiney, the central railway loading point is near Brignoles where the 30-ton trucks are weighed-in before discharging their contents into the receiving bunker. A sample is taken from each truck load for analysis. The ore is either conveyed to the stock piles or to the crusher building where the oversize from a 150 mm screen is crushed in a jaw crusher operating at the rate of 300 tons per hr. Crushed ore is stocked in silos located above a railway siding. It is discharged by pneumatically operated discharge gates into 60-ton railway cars. The normal size train of some 12 to 14 cars can be filled in 10 min. Two trains a day are loaded for the journey to the alumina plant at Gardanne, some 60 km distance.

Alumina plants in Marseille region

Within 25 miles of Marseille are located three of France's major alumina plants—close to the bauxite mining region as well as rail, barge, and sea transport facilities. The largest of these plants is that at Gardanne, operated by Pechiney and located adjacent to low-grade lignite deposits. It is, in fact, these deposits which governed the plant's location, for the lignite mined is not of sufficiently high quality to make economic its transport to the bauxite mining area. It is the most readily available fuel to meet the steam requirements—some 2500 metric tons per day —of this alumina plant.

Gardanne started production in 1900, with capacity steadily increased since then, and more than trebled since 1948. The plant is now undergoing a further modernization and expansion program to bring its daily capacity to 750 metric tons of alumina early in 1958. The plan operates on the Bayer process.

The bauxite arriving by train from Brignoles is first crushed by a hammer mill to 75 pct −20 mm and then passed into a three-section ball mill where the ore is wet-ground with the attacking liquor. In the first two section of the mill, grinding is accomplished by steel balls, while in the third section steel cylinders are used. The mill is in a closed circuit with the classifier overflow being under 250μ.

Continuous attack in autoclaves

Pechiney, faced with high bauxite mining costs, has expended considerable effort in reducing alumina production costs to the lowest possible level. One step in this direction has been to make the extraction of alumina a continuous rather than a batch process. Continuous flow has meant not only automatic controls with consequent reduced manpower, but also higher extraction rates and the possibility of considerably reducing steam requirements.

Pechiney is, thus, completely changing over to continuous alumina extraction by installing four lines of nine autoclaves each at Gardanne. The pulp-caustic soda mixture, discharged from the ball-mill circuit, is pumped into the first of the 35 cu m vertical cylindrical autoclaves. Steam under a pressure of about 25 kg per sq cm enters the last three autoclaves where it heats the contents to a temperature of 230°C. The steam enters at the bottom, while pulp from the preceding autoclave enters at the top. The mixture passes out of each autoclave through a vertical pipe located at the center of the autoclave and emersed in the pulp. Upon leaving each autoclave the pulp passes into a separating chamber where the steam is exhausted at the top and the pulp passes out the bottom into the succeeding autoclave. Steam from the separators on the last autoclaves is passed successively through all preceding autoclaves and separators in a countercurrent fashion to the movement of the pulp.

Thirty-ton trucks bring bauxite to this central railway loading point near Brignoles. The ore is crushed to −150 mm and automatically loaded into a 12-car train.

Heat exchangers in extensive use

Pulp discharged from the last autoclave enters heat exchangers where it heats the pulp entering the line and is discharged at a temperature of 125°C. Steam leaving the separators on the first three autoclaves is also passed into heat exchangers to recover as much heat as is possible.

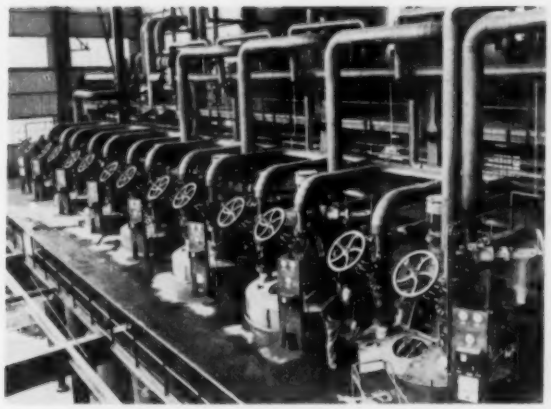
By means of an elaborate series of heat exchangers throughout the plant, as well as the high heat efficiency of the continuous autoclave extraction technique itself, it has been found possible to minimize the heat required for the production of alumina. Such heat efficiency has resulted in a reduction in steam requirements from 9 tons per ton of alumina in 1946 to less than 4 tons at the present time and less than 3 tons when all continuous autoclaves will be in operation. Furthermore, increasing mechanization has resulted in reducing the number of men required to produce 1 metric ton of alumina per day from 4 in 1946 to less than 1 at the present time.

Other firms have taken notice of developments taking place at Gardanne, and Kaiser Aluminum & Chemical Co., as well as Ormet Corp. have taken out license from Pechiney for construction of continuous alumina extraction units in the U. S.

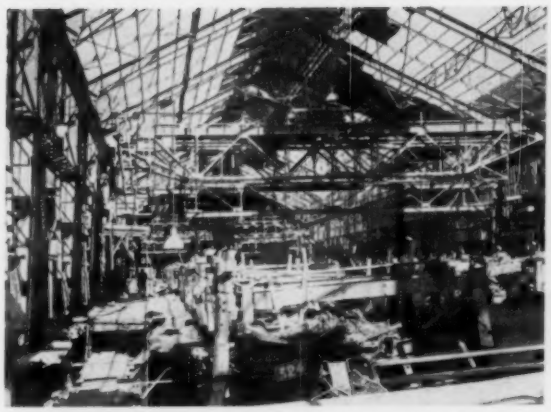
Extraction efficiency in these autoclave units is 85 to 88 pct of the alumina in the bauxite. One part of the undissolved alumina remains unattacked, while the other part is rendered insoluble by the silica which forms a silico-aluminate of soda. This loss of both alumina and caustic soda must be carefully considered when mining of the higher silica bauxite ores.

Separation of red mud

Upon being discharged from the heat exchangers on the continuous autoclave lines, the liquid is diluted and the insolubles—iron oxides, silica, and alumina combined with silica—known as *red mud*—are separated in batteries of continuous decantation lines.



Bauxite is attacked in a continuous process in this line of 35 cu m autoclaves at the Gardanne plant. Tanks at top of picture, separate the caustic pulp from the steam in the autoclave discharge. Counter-current passage of steam is used.



At La Saussaz, flood waters of the Arc river roared through the aluminum plant several days before a visit by Journal of Metals' Managing Editor. The resulting explosion of pre-baked aluminum cells all but demolished the plant; however, at last reports, the plant is once again in operation.

The red mud contains a considerable quantity of caustic soda which must be removed. This is accomplished in a washing plant by five-stage decantation with counter-current circulation of washing water. The caustic recovery is 98 pct effective, but the discharged red mud still contains an average of 5 kg Na_2O per metric ton of alumina produced; this loss represents some 5 pct of the total caustic consumption. The washing water from these circuits is used to dilute the pulp leaving the autoclaves.

The red mud is discarded, although during World War II, Pechiney did produce limited quantitites of iron from this mud which contains more than 50 pct Fe. The operation is, however, generally regarded as uneconomic, since the mud also contains some 10 pct SiO_2, making it difficult to flux.

High efficiency pumps of Pechiney design

One of the critical problems encountered in the continuous autoclave extraction process is that of pumping a heavy density pulp and corrosive liquor at high temperatures and pressures. One Pechiney engineer has now perfected an automatically controlled two-membrane pump capable of pumping 130 cu m per hr at a pressure of 25 kg per sq cm at a temperature of more than 200°C. The latest design pump at Gardanne has only one oil-operated membrane with the oil pressure automatically controlled on the basis of the normal position of the membrane.

Decomposition tanks of 40,000 cu m

Passing from the decantation tanks, the liquor is first filtered to remove the last trace of red mud. Again in an effort to conserve the greatest quantity of heat, the warm liquor from the decantation tanks passes into plate-type heat exchangers where it is cooled to 50°C by the liquid passing from the decomposition tanks.

In the decomposition tanks the chilled, diluted liquor is seeded with fine alumina powder. The circulating load of alumina for seeding purposes represents three times the daily output of the Gardanne plant. Decomposition takes a maximum of 4 days, thus requiring decomposition tanks with a total of 40,000 cu m capacity.

The precipitated alumina in the caustic liquor is pumped through the forementioned heat exchangers to filters for removal of the alumina. While French designed filters are now in use for this purpose, Pechiney is now experimenting with an EIMCO plate filter.

The caustic liquor passes to multiple-effect vacuum evaporators—another large consumer of steam—where liquor is reconcentrated for use in the continuous autoclave circuit.

Vanadium recovery

Alumina from the first filter is rewashed on a second drum filter for recovery of caustic soda and vanadium in the wash water. A vanadium salt at Gardanne is produced in the amount of 300 g V_2O_5 per metric ton of alumina. Its recovery from the wash water is by chilling and seeding with the same salt.

From the rewashing filter, the alumina enters one of a battery of oil-fired Traylor kilns heated to 1200°C and discharging into a short cooling kiln. Air entering the cooling kiln is used as the combustion air for the oil burners, while air leaving the kiln enters an electrostatic precipitator where recovery of 99 pct of the alumina in the fume is accomplished.

Dried alumina discharged from the kiln is pumped through pipes as an alumina-air suspension to storage kilns prior to being discharged into the specially designed aluminum railway cars for transport some 250 miles to Pechiney's aluminum reduction works in the French Alps and Pyrenees.

At present, for every metric ton of alumina, the Gardanne plant consumes the following: 2.4 tons of bauxite, 0.7 tons of coal, 0.08 tons of caustic soda, and 0.0130 tons of fuel oil. During 1958 these figures will be reduced when the four continuous autoclave extraction lines come into full operation.

Aluminum reduction works

Located traditionally in areas of great hydroelectric potential, aluminum production in France is centered in the French Alps, although there is a smaller output from several hydroelectric powered plants in the Pyrenees region. Reduction works are operated by two firms, of which the larger is Pechiney.

The valley of the Arc River, high in the Alps not far from the Italian border, is the focal point of

production with its hydroelectric potential now on the order of 1600 million kw-hr. The first aluminum production in the valley was at La Praz in 1893, followed by La Saussaz in 1903, and St. Jean de Maurienne in 1907.

St. Jean, Europe's largest aluminum plant

The plant at St. Jean de Maurienne was extended considerably during World War I and remained at the level of some 20,000 tons until 1945. Since then the number of prebaked electrode pots has been increased considerably and now numbers three series of 48 pots each and one series of 102 pots, operating between 35,000 and 80,000 amps. It was in 1953 that the plant's present scope began to take shape with the installation of the first söderberg electrode pot line. There are now 152 söderberg reduction cells, each operating at 100,000 amperes, so that the plant's present capacity is rated at some 70,000 metric tons annually, of which 35,000 is from the söderberg cells.

Raw materials for the plant are supplied by other units of Pechiney. Alumina comes from Gardanne and two smaller plants with one 18-car train carrying 1150 metric tons of alumina arriving three times a week. Cryolite is produced synthetically at the Salindres plant from fluorspar mined at Pechiney mines near the town of Langeac. Electric power was, prior to nationalization in 1946, produced at Pechiney hydroelectric power plants in the valley of the Arc, and one in the St. Jean plant itself. Prebaked electrodes are produced at St. Jean. Thus, the firm is almost self-sufficient in its raw material requirements, which for the production of one metric ton of aluminum amount to 1900 kg of alumina, 50 kg of cryolite, 450 kg of anodes, and 16,500 kw-hr of electricity.

As for the raw materials for electrodes, the plant is anything but self-sufficient. Because of the high rate of consumption of anodes, it is important that they be extremely pure so as not to introduce deleterious elements into the aluminum. It is for this reason that both prebaked and söderberg anodes are made largely from American petroleum coke or German pitch coke which have an ash content of only 0.4 pct. Such petroleum coke is blended with pitch. In order to increase the life of prebaked electrodes from an average of 18 to 21 days, Pechiney has found that a coating of aluminum is necessary. Such a coating amounts to 50 kg of aluminum when the electrode is dipped into an aluminum bath, but the weight is less when a spraying technique is used.

The 100,000 amp soderberg cells

Continually striving to reduce costs by installation of equipment of the highest efficiency, Pechiney engineers have for some years designed much of their own equipment. They have long experimented with many designs of aluminum reduction cells. The results of this was the construction in 1953 of a completely new reduction unit at St. Jean using cells of Pechiney's own design; these are the söderberg electrode cells of 100,000 amps. Not only did their size exceed anything previously built, but they incorporated vertical pin söderberg electrodes for the first time. They have a Faraday efficiency between 90 and 92 pct and have proven so successful at St. Jean that additional pot lines were installed, making a total of 152 cells at present. Pechiney has licensed these pots abroad; in the U. S. and Canada licensees are Anaconda, Alcoa, Alcan, Harvey, Ormet, and Reynolds. Pechiney now has plans for 150,000-amp reduction pct.

Foundry features continuous casting

In the foundry at St. Jean, aluminum from both types of reduction pots is poured into one of several 9-ton capacity oil-fired furnaces heated to 750°C. A certain amount of dross is skimmed from the metal in these furnaces and returned to the reduction cells, while the metal is transferred to an electric holding furnace prior to casting.

The plant has several continuous lines for casting two slabs at a time to the desired length. The aluminum is poured into a launderer which splits the metal into two streams leading to water-cooled molds. These molds are of two designs: one with the bottom parallel to the top and only 65 mm in depth, and the other with the long length of the mold having a depth of 20 cm at the sides and 15 cm at the middle. The former type mold is used on the larger slabs. Solidification takes place at the rate of about 2 cm per min, but with solidification taking place on several fronts simultaneously, it is possible to allow the bottom of the mold to descend at the rate of 9 cm per min. Slabs from 325 mm to 1115 mm in width are cast by this technique.

Wire rods are cast continuously on a casting wheel revolving in a vertical plane. A band of steel around the outside of the grooved casting wheel

Europe's largest aluminum reduction works, the St. Jean de Maurienne plant of the Pechiney firm, has a capacity of 70,000 metric tons per year, half from prebaked cells, and half from söderberg cells. The plant, along the banks of the Arc river, has its own hydroelectric power plant.

holds the liquid metal in place until solidification takes place after about half of a revolution. Casting is at the rate of 10 m per min, and up to 1600 kg per hr has been achieved by this machine made by the Italian firm of Properzi. The wire rod passes into a rolling mill made up of 13 sets of rolls. This mill rolls wire to 8 mm diam at the rate of 600 m per min.

Super-pure aluminum

While the aluminum produced at St. Jean is 99.5 to 99.8 pct pure, this is not sufficient for some purposes, as for example reflectors. For this reason Pechiney, at its Mercus plant in the Pyrenees, developed an electrolytic cell for refining the 99.8 pct metal to 99.9945 pct and more. This is called the *three-layer refining process.* Aluminum together with copper—to increase the density of the metal—is charged into the bottom of the cell. Above this is the electrolyte made of 60 pct $BaCl_2$, 35 pct $AlF_3 \cdot 3NaF$, and 5 pct NaCl in molten form. The anode is the bottom of the cell, and the cathode is at the top. Impurities remain at the bottom with the electrolyte acting as a filter, particularly for magnesium. The super-refined aluminum forms at the top of the cell on the cathode. The Faraday efficiency of the cell is 95 pct; the cell temperature is 750°C; and the current is 18,000 amps. The Mercus plant produces about 2000 metric tons per year of high purity aluminum by this technique. Pechiney has licensed Reynolds with the three layer aluminum refining process in the U. S.

French aluminum production

Prewar French aluminum output was on the order of 30,000 metric tons; this rose to 60,000 tons in 1950, and 1956 output was 149,000 metric tons, 127,000 of which was from Pechiney. Production has been largely for the interior market, for aluminum consumption is mounting steadily in France; primary aluminum consumption, which was only 55,000 metric tons in 1950, reached 130,000 tons in 1956.

Postwar expansion of aluminum capacity has largely been in the Alpine regions, but readily available hydroelectric sites in this area are no longer great in number, and electrical power consumption has been rising astronomically. Furthermore, with electric power nationalization in 1946, aluminum plants could no longer build their own power plants; instead they must now purchase power from the national grid in competition with other consumers. For these reasons it appears as if the French aluminum industry has almost reached the limit of its output in this region. But aluminum demand is mounting steadily in France, and the export possibilities appear attractive as well.

Future French production

There is an important new source of power developed in France since World War II which may be of great importance in expanding aluminum capacity. This is the natural gas field of Lacq in the Pyrenees. Experimental work is already underway to develop cheap electric power from this source. Its success will result in a considerable expansion of aluminum capacity in this region.

Bauxite reserves appear adequate for the future needs of the country. While mines may keep getting deeper in the Department of Var, it appears as if mines in the Department of Herault, to the west, may be capable of expanded production. Furthermore, little exploration of bauxite has taken place in the Department of Bouches du Rhône where the mineral was first discovered. This area has largely been held in reserve for future needs of the industry.

There are 152 of these 100,000 amp söderberg cells at the St. Jean de Maurienne plant of Pechiney where this high ampere, vertical pin electrode, cell was first put into operation. A number of American firms have been granted licenses for installation of these cells.

The African projects

Cheap hydroelectric power possibilities together with vast bauxite reserves has strongly oriented both French aluminum producers—Pechiney and Ugine—toward the production of aluminum in French Equatorial Africa.

The first project, based on a large-scale hydroelectric dam, is that of ALUCAM—Africa's first aluminum smelter. It commenced operation last spring at Edea in the Cameroons, but full scale output of 45,000 tons is not expected to be achieved until July 1958. Power costs reportedly on the order of 2 mils per kw-hr—less than one third of that in France—is expected to make this project more than competitive in the European and South American markets. Initially alumina will be shipped from France, but at a later date alumina will be delivered from the Fria consortium project further north on the African coast. The ALUCAM plant will have 208 söderberg cells of 100,000 amps each.

Another aluminum reduction plant project—this one even larger—is being carried out in French Guinea in conjunction with a multi-national group. The project includes the construction of a hydroelectric power plant on the Konkouré River and an aluminum reduction works of 200,000 tons capacity. Alumina is to be supplied by the Fria project in amounts up to 480,000 tons per year.

From these African projects and probable expansion schemes in the Pyrenees it appears that France together with its African countries will be in a strong position to supply aluminum to the domestic market as well as supply many of the European and South American markets.

The Automatic Spectro-Lecteur

TO provide a rapid method for analyzing aluminum samples, Pechiney, the leading French producer of aluminum, sponsored research which led to the development of the **first, instantaneous, direct-reading spectrograph**, the Spectro-Lecteur. Several years ago the instrument was put on the French market by Compagnie Française de Cinema and won widespread acclaim in metallurgical research laboratories and plants. Finally, the Spectro-Lecteur has reached the U. S. and is now being marketed here by Intercontinental Electronic Corp. of Mineola, New York, a combination of five technical firms and banks in France and the U. S.

Replacing photographic methods

Spectrochemical analysis of alloys is based on the intensity ratio of two spectrum lines: one belonging to the basic metal, and the other to an element contained in the alloy. In photographic analysis, the value of this ratio is obtained through measurement of the density of the plate, but in the more recently developed direct-reading methods, this value is obtained through electrical measurement of potentials across the terminals of condensers loaded by photomultipliers. Because of its greatly increased speed and accuracy, this latter method is replacing photographic techniques.

Still further advances

The new method still involves an integration time before reading, using as many photomultipliers as there are lines to be recorded. Such an integration masks erratic changes of intensity during the time of analysis, and only the final result is shown. But this is no longer necessary, and the technique of metallurgical analysis based on a direct and instantaneous reading was first realized with the development of the Spectro-Lecteur.

Simplicity of construction

The Spectro-Lecteur records directly the intensity ratio of the two lines automatically and instantaneously. Only two photomultipliers are employed to receive the line radiations: one being set to receive radiations from the standard line, while the other travels along the focal plane of the spectrum to detect radiations from the line of each element in turn. The output of the two photomultipliers are fed to two identical amplification channels, feeding a potentiometer which records the instantaneous value of their ratio on a graph.

Simplicity of operation

An important feature of the Spectro-Lecteur is its almost completely automatic operation. After preliminary adjustments, all that is required is the placing of the specimen to be analyzed in the sample holder, and the pressing of a button. A time clock controls the rest.

After a presparking time of the sample, the traversing mechanism is set in motion, causing the analysis photomultiplier to follow the focal point of the spectrum. A Program Ruler determines where the photomultiplier is to stop, and thus what elements are to be analyzed. At each stop the recording potentiometer is set in action and traces on the graph the evolution of the intensity ratio of the two photomultipliers. The time clock determines the length of each analysis and restarts the traversing mechanism after each stop.

Speed and accuracy

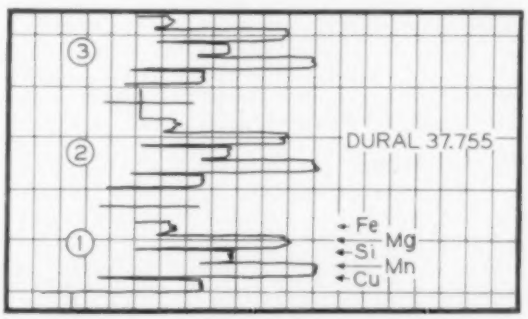
The average time for complete analysis of an alloy under routine conditions is about 1 min and 30 sec. Furthermore, the Spectro-Lecteur can be changed over from one type of alloy to another, the base metal of which is different, within 2 min.

Based on a great number of analyses obtained from various alloys under different conditions, it has been established that the standard deviation of the method is as low as ±1 pct. This represents a three-fold improvement in accuracy over the photographic method.

The instantaneous sensitivity is such that it is possible to record lines so weak that by photographic method several minutes of exposure would be necessary. The high sensitivity of the instrument permits analysis of pure aluminum for traces as low as 0.003 pct Fe or Si.

The system, including only two photomultipliers, obviously demands only two electronic circuits. Breakdowns are, thus, less frequent than in the case of other direct reading instruments which include at least 20 circuits.

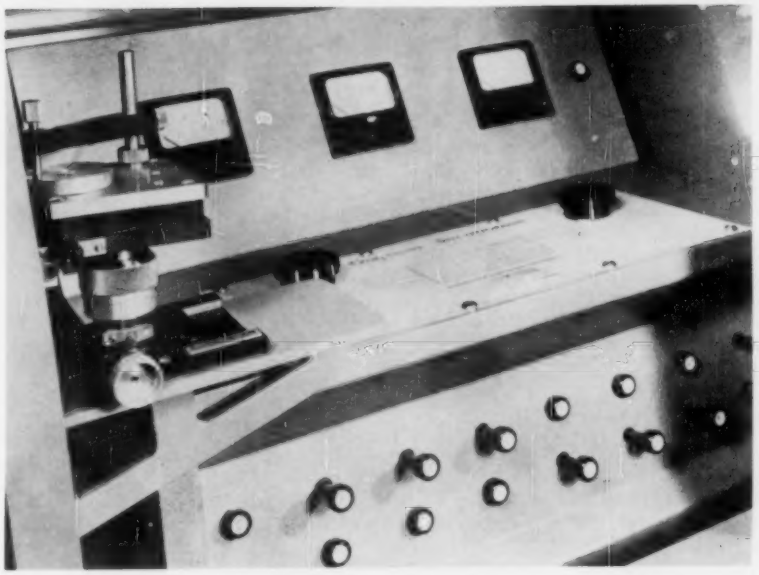
So, it would seem that the Automatic Spectro-Lecteur may indeed find a very definite place in American metallurgical analysis.



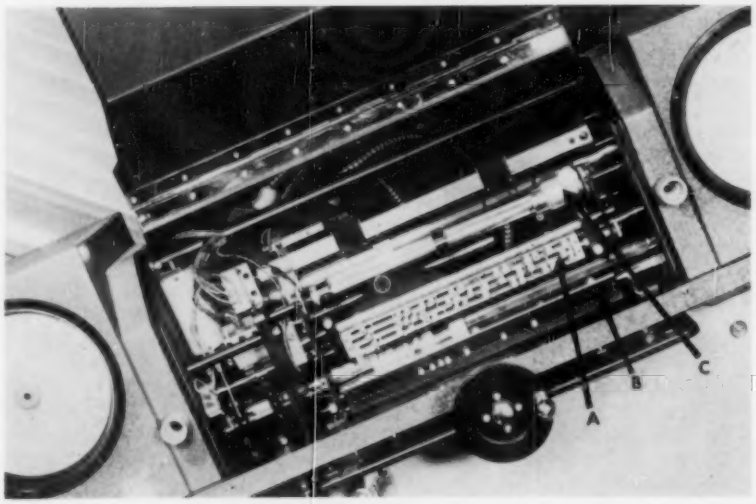
An essential characteristic of the direct and instantaneous method is to give not only the final result of the analysis, but also information on the time necessary to obtain stabilization of the spectrographic lines, the quality of emission, the probability of error, the suitability of excitation conditions, and the homogeneity of samples. Above is the graph obtained in the analysis of one Dural aluminum sample.

The advantage of the automatic Spectro-Lecteur is that its simplicity of design speeds and improves metallurgical analysis. An unskilled operator, without special qualifications, is able, with a few days training, to learn the manipulation of the apparatus.

The sample to be analyzed is clamped to the surface of the Petrey table at the left of the figure. Below the sample is positioned a carbon rod; thus spark excitation occurs between a plane to point gap. The spark generator cabinet, at right, has provisions for changing the excitation by addition of capacitances and inductances



A close-up of the Direct Reading Head. The main parts are: A) Analysis Ruler, B) Program Ruler, and C) Temperature Compensator. Each Program Ruler contains a number of slots corresponding to the elements in the sample to be analyzed, and sensitivity blocks which correspond to the amplification factor required relative to the intensity of each line.



Aluminum in Electrical Engineering

JOURNAL OF METALS' Managing Editor, F. W. Starratt, was present when an international conference convened in London to discuss the use of aluminum in electrical conductors and the most perplexing problem of jointing.

At the Institution of Electrical Engineers, an imposing building on the Victoria Embankment in the heart of London, some 450 metallurgists and electrical engineers gathered for the symposium, "Aluminium in Electrical Engineering". This was the latest in an almost annual series of technical meetings on aluminum organized by The Aluminium Development Association, a technical and consultative body, sponsored by the aluminum industry of Great Britain with the object of encouraging the correct and increasing use of aluminum and its alloys.

Economics of aluminum in electrical engineering

Dr. E. G. West, technical director of The Aluminium Development Association and a member of AIME, drew attention to the economic background of aluminum and indicated the long-term future trends.

"Known bauxite reserves have been conservatively estimated at some 2000 million tons, and in addition, all the clays and many other minerals contain sufficient aluminum to make them attractive for future exploitation.

"Present and planned productive capacities are shown in Table I, from which it is clear that within the next few years world production will be 5 to 5½ million tons and by 1965 between 6½ and 7 million tons. In addition, the aluminum industry is making increasing use of refined secondary metals, which play a major part in the economy. It is likely that world secondary production is around 25 pct of world primary production and this can be expected to increase in about the same proportion as the output of virgin metal."

Thus, "The long-term supply of aluminum is particularly favorable by comparison with the other nonferrous metals concerned, due to the greater abundance of high grade ores and the establishment of very large modern production units in many parts of the world. There are ample facilities for further expansion."

Turning to electrical conductors, ". . .it seems certain that the many applications of aluminum already established will continue acceptable. For certain applications, copper is still, and may well remain, the most suitable of conductor materials and therefore it seems reasonable to suggest that copper should be used basically for these essential purposes. This will allow a more rapid increase in the adoption of electrical equipment, and an increase in the power used per capita than would be the case if reliance were placed entirely on a sufficiency of copper for all purposes. In any case, the rate of increase in capacity for generating plant exceeds the rate of increase in copper output, and alternative conductor materials must therefore be more in demand."

Jointing processes for aluminum

In its use as an electrical conductor, the problem of jointing has presented by far the greatest obstacle for aluminum. The subject was introduced by the paper, "Fundamentals of Jointing Processes for Aluminum" by J. C. Bailey of The Aluminum Development Association and P. Gregory of British Insulated Callenders Cables Ltd.

The major difference between copper and aluminum is the nature of the oxide film. The aluminum

Table I. Primary Aluminum Production and Planned Capacity, Thousand Metric Tons

Country	Production 1955	Capacity (actual or planned) 1955	1960	1965
Europe	549	634	750	850
Asia	72	77	113	123
Africa	—	—	45	200
Australia	1	7	13	13
USA	1420	1460	2300	2500
Canada	551	590	1000	1300
South America	3	10	90	170
USSR, etc.	600	700	1235	1500
Total	3196	3478	5546	6656

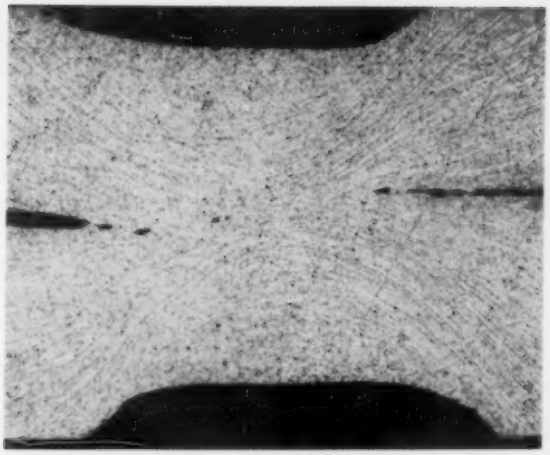


Fig. 1—Cold weld made in aluminum sheet by heavy deformation. 75X, reduced 20 pct for reproduction.

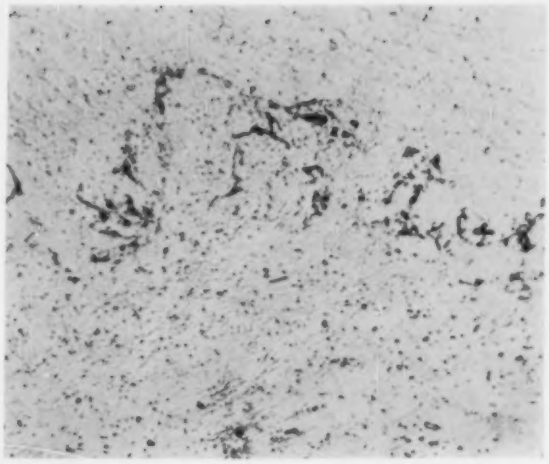


Fig. 2—Cold weld made with minimum deformation, aided by ultrasonic vibration. The oxide has been well dispersed. 300X.

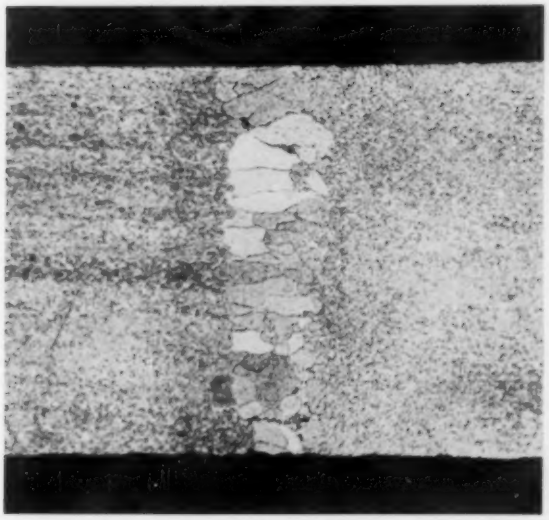


Fig. 3—Resistance butt weld in 0.132-in. diam aluminum rod. 20X.

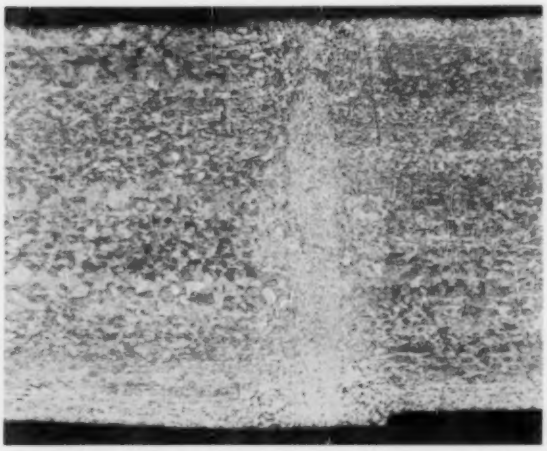


Fig. 4—Flash butt weld in 3/8-in. diam aluminum rod. 10X, reduced 35 pct for reproduction.

film is amorphous, hard, adherent, and non-conducting. "Immediate application of moisture-free petroleum jelly or other suitable agent for excluding air largely prevents growth of the film, both on aluminum and on copper. . . . The aluminum oxide film is attacked by fluorides and chlorides, which are therefore used in welding or soldering fluxes, and is dissolved by caustic alkalies. . . . The film is insoluble in liquid or solid aluminum metal, and this may account in part for its successful removal by purely mechanical methods—fragmentation by ultra-sonic vibration or displacement and dispersal by deformation of the underlying metals, as in pressure welding and compression jointing."

Attention was drawn to the advantages of fusion welding, resistance welding, and pressure welding, which yield permanent low-resistance joints, and to brazing which is equally suitable. It was suggested that crimped joints involving deformation of the conductor are particularly appropriate to aluminum, while methods familiar to copper, such as bolting, clamping, and soldering can be successfully applied with appropriate modifications.

Fusion welding: "The relatively low melting point of aluminum and its high specific heat favor fusion welding; and the increased resistivity, over that of copper, favors resistance welding. The higher coefficient of linear expansion might be considered a disadvantage, though in jointing it has not appeared to have significant effect." On the other hand, "The tenacious bond between the oxide and metal, and the poor *wettability* of aluminum by molten low temperature solders, are basic properties that accentuate the difficulties in making good soldered joints. . .

"Shielded-arc fusion welding processes. . .have been fully developed for welding aluminum in other fields of use, have been successfully applied to electrical joints. . ."

Resistance welding: With aluminum conductors. . . ". . .fusion occurs in most practical processes, and is sometimes regarded as beneficial in assisting the removal of oxide films and reducing the amount of surface preparation required. The material in the weld zone therefore generally contains at least

traces of cast metal and is surrounded by fully or partly annealed heat-affected regions.

"In butt welding. . .as a result of the softening in the joint area, there is an increase in the cross-section in the form of a smooth bulge." However, "In flash butt welding the parts are first brought into light contact and then separated to cause arcing or flashing, with melting at the intended joint surfaces. The flashing period is terminated when the power is switched off and simultaneously the parts are brought rapidly into contact. This action produces a fin or flash, and is a very effective means of removing oxide and most of the molten metal from the joint."

Torch brazing: "This is a simple process carried out at a temperature of approximately 600°C on aluminum, and is regularly used . . . on . . . small and medium cross sections. A flux is used . . . and must be completely removed afterwards. Once the two parts to be jointed have been raised to the brazing temperature, actual jointing is very quickly accomplished, the aluminum-silicon alloy filler metal being drawn by capillary attraction between the abutting surfaces of the joint. Because of the very small thickness of filler metal in the joint, and the perfect contact between the metal surfaces, the resistance is uniformly low and the joint itself is mechanically strong."

Soldered joints: "During the last few years many hundreds of solder alloys have been proposed for aluminum. In the main, however, alloys containing appreciable amounts of zinc or tin are used for *tinning* the surface on account of the ease with which these metals will alloy with aluminum . . . Fluxes for aluminum soldering may be divided into two types referred to as organic and reactive. The former usually contain an organic substance, such as triethanolamine, acting as a vehicle for fluorides which are the active fluxing agents. . . Reaction fluxes are usually mixtures of chlorides and fluorides and are rather more efficient, but they operate at higher temperatures and their residues tend to be corrosive." In addition, "Oxide may be removed mechanically by abrasion under molten solder . . ."

Pressure welding: "Compared with most metals, aluminum is outstandingly suitable for jointing by the aid of pressure and deformation. One reason is that the oxide film is easily ruptured by deformation, so exposing clean, unoxidized metal surfaces suitable for good contact.

"Cold welding normally involves extensive deformation in the vicinity of the welds and is carried out at room temperature, using pressures in the range of 12 to 18 tons per sq in. depending on how the deformation is effected . . . high strength efficiencies are only obtainable when the parts are perfectly free from grease contamination. Nevertheless, aluminum materials are readily welded after preliminary cleaning which is limited to simple degreasing and scratch brushing . . . A recently developed method of avoiding the high deformation required is the application of ultrasonic vibrations at the interface while relatively light pressure is applied. Good welds in aluminum have been made in this way with only 5 pct total deformation."

Crimp jointing and bolted connections are two types of connections employed for aluminum conductors. With the former "a sleeve fitting is indented or circumferentially swaged with considerable deformation to produce tight contact on a conductor". Bolted connections are "characterized by generous contact areas which are maintained under pressure by bolts or clamps; a pressure of 1500 to 2000 lb per sq in. on the superficial contact area has been recommended."

Aluminum as an electrical conductor

The total world production of electrical energy has increased from 459 billion kw-hr in 1939 to some 1200 billion kw-hr in 1955, and this continuing expansion means a corresponding demand for conductor metal to be used for the generation, transmission, distribution, and utilization of electrical energy. The amount of electrical apparatus now manufactured is so great, indeed, that copper has repeatedly been in short supply.

The economic incentive to use aluminum for electrical conductors other than for overhead transmission lines was not great early in the century because this metal was more expensive than copper. However, the price differential between aluminum and copper ingot narrowed markedly in the immediate post-war period until, in 1945-46, copper for the first time cost more per ton than aluminum.

R. Cloke and R. Fyfe of the Eastern Electricity Board of the U. K. reported that it was apparent "that all-aluminum could readily be substituted for copper for low voltage lines with considerable saving in conductor costs, and a number of trial lines were elected in various parts of the country about 1951. Further increases and instability in the price of copper encouraged Electricity Boards to change more and more to aluminum, not only for low voltage lines but also for 11 kv and 33 kv lines for which steel-cored aluminum or aluminum alloy conductors could be used."

The Board found that it had to surmount two main difficulties in its use of aluminum conductors. First, "Due to their high strength:weight ratio steel-cored aluminum and aluminum alloy conductors are more prone to vibration, leading in severe cases to breakage of binders and conductors. This problem can be mitigated by restricting the conductor tension . . ." Second, "For equal electrical conductivity, aluminum conductors are about 30 pct larger in diameter and this increases the wind and ice loading, thereby necessitating stronger supports.

"In the Eastern Board's area more than 200 route miles of all-aluminum low voltage lines have been erected during the past few years." And, "Remarkably few difficulties have been encountered. . ." In the same area ". . . there are now well over 100 miles of light 11 kv lines with alloy conductors in service, and experience to date has been quite satisfactory . . . More than 800 miles of steel-cored aluminum lines exist in the Eastern Board's area and, in general are giving satisfactory service . . . apart from a certain amount of vibration trouble . . ."

Range of uses

Other papers discussed the use of aluminum in high voltage transmission lines, insulated conductor cables, busbars, transformers, and telecommunication cables.

The symposium served to dramatize the picture of aluminum with its high electrical conductivity, light weight, and corrosion resistance filling an ever-widening demand for electrical conductors. Great strides appear to have been taken toward overcoming the metal's jointing problems—up to this point its chief deterrent toward wider acceptance by the electrical industry.

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AIME NEWS

Heading the new Editorial Staff of the JOURNAL OF METALS are, (left to right): James J. Burke, Associate Editor; Robert W. Shearman, Secretary-Treasurer of the Metallurgical Society of AIME; and F. Weston Starratt, Managing Editor. They will direct the New Look of JOURNAL OF METALS, which now offers better and enlarged editions with greater news coverage to keep up with the rapidly growing metals industry.

Metallurgical Society Bylaw Changes

At a meeting of the Board of Directors of the Metallurgical Society of AIME on Nov. 6, 1957, certain changes in Bylaws were voted on favorably. These amendments were recommended to the AIME Board of Directors for favorable action at their meeting on Nov. 18, 1957, so that the Metallurgical Society can implement the actions by the time of the AIME meeting in February, 1958. The changes are indicated by the italicized words in the Bylaw articles and sections as follows:

Amended Bylaws

Article V

Officers

Section 1. The officers of the Society shall consist of President, Vice President, *Secretary*, and *Treasurer*.

Section 3. The Board of Directors shall consist of the following:

a. President
b. Vice President
c. Past-President
d. *Secretary*
e. *Treasurer*
f. As approved in amendment published in August JOURNAL OF METALS, p. 1073.

Section 4. The *Secretary* shall be appointed by the Board of Directors for a term of one year at a salary consistent with his responsibilities, subject to the approval of the Board of Directors of AIME. *The Treasurer shall not be a staff member of The Metallurgical Society or of the AIME.*

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Metallurgical Society 1958 Award Winners

The Metallurgical Society will confer the following honors during the Annual AIME Meeting in New York, February 16 to 20, at the Hotel Sheraton-McAlpin.

Robert W. Hunt Award Medal to **G. W. Healy** and **D. C. Hilty.** To be presented at the annual dinner on Tuesday evening, February 18.

The **J. E. Johnson Award,** comprising a certificate and a $100 check, will be awarded to **Richard H. White** at the annual dinner on Tuesday evening, February 18. Born in Oil City, Pa., he worked for Oil Well Supply Co., a subsidiary of U. S. Steel Corp., during his summer vacations, while attending Case Institute of Technology. He received a B.S. degree in mechanical engineering in 1939, followed by a position with U. S. Steel's Ohio Works in Youngstown, as a practice apprentice in the power and fuel dept. Three years later, he transferred to the blast furnace dept. as assistant to the superintendent, and rose to assistant blast furnace superintendent in less than six years. Two weeks after ground was broken for the Corp.'s new Fairless Works, Mr. White was appointed as the first superintendent of blast furnaces at the Delaware Valley project.

Extractive Metallurgy Division Award consisting of a gold medal and a certificate for each of the recipients, will be presented to **John N. Ong, Jr., Milton E. Wadsworth,** and **W. Martin Fassell, Jr.** at the EMD luncheon on Wednesday, February 19. **John N. Ong, Jr.** is a native of Rio Tinto, Spain and was educated in schools in Johannesburg, South Africa, and Plumtree, Southern Rhodesia. From 1945 to 1948, he served in the Armed Forces of the United States. After being discharged from military service, he enrolled at the University of Utah, receiving his B.S. in chemical engineering in 1952 and a Ph.D. in

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Award Winners

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metallurgy in 1955. Dr. Ong worked with the Uranium Corp. of America, Utah until 1956 when he was appointed assistant professor of mechanical engineering at Washington University, St. Louis. **Milton E. Wadsworth** hails from Salt Lake City. He received a B.S. in metallurgical engineering in 1948 from the University of Utah and a Ph.D. from the college in 1951. Dr. Wadsworth remained at the University, starting as an instructor in metallurgy, and is now serving as an associate professor. His main research interests have been in the field of surface chemistry, particularly as applied to metallurgical problems. He has published over fifteen papers, mostly in the field of metallurgy, including studies in roasting, flotation, corrosion, reduction and leaching. **W. Martin Fassell, Jr.** was born in Salt Lake City. He attended the University of Utah, receiving a B.S. degree in 1942, his M.S. degree in 1947 and a Ph.D degree in 1949. From 1944 to 1946, Mr. Fassell served in the U. S. Navy as executive officer aboard the U.S.S. Cooner. His many various positions have included associations with the U. S. Bureau of Mines, as laboratory assistant in research, the University of Utah as quiz class instructor in chemistry, and later as a research fellow in the University's department of metallurgy, junior plant control chemist for the General Chemical Co., E. St. Louis Works, and director of research for Howe Sound Co. in Salt Lake City. The paper selected for the 1958 Award is *Kinetic Study of the Oxidation of Sphalerite.*

Benjamin F. Fairless Award will be presented to **Hjalmar W. Johnson** at the annual banquet on Wednesday, February 19. Hjalmar W. Johnson, who hails from Joliet, Ill., began his career in steel in 1915, after graduation from high school. He joined the Illinois Steel Co. at Joliet which was a part of U. S. Steel Corp., and worked in the blast furnace dept. He later left to attend the University of Illinois and received a B.S. degree in engineering in 1922. Following this, Mr. Johnson was employed by the South Works of the Illinois Steel Co., attaining the post of general foreman of three blast furnaces. In 1929 he joined Inland Steel Co., and rose to the position of assistant superintendent of Inland's Indiana Harbor Works in 1942. In 1946 Mr. Johnson was elected vice president in charge of steel manufacturing, and a director in 1954. A former director of AIME, he was the recipient of the Institute's J. E. Johnson, Jr. Award in 1933 and the American Iron and Steel Inst. Medal in 1941. In 1957, Mr. Johnson received an honorary doctor of engineering degree from Michigan College of Mining and Technology.

A. H. COTTRELL

A certificate will be presented to **Alan H. Cottrell, Institute of Metals Division Lecturer for 1958,** preceding his address on Wednesday morning, February 19. His topic will be the *Theory of Brittle Fracture in Metals.* A native of Birmingham, England, Mr. Cottrell studied metallurgy at Birmingham University, receiving a B.S. in 1939 and a Ph.D. in 1942. At the same college, he served successively as lecturer in metallurgy and professor of physical metallurgy. During the war, he worked on metallurgical problems for the Ministry of Supply and the Admiralty. Dr. Cottrell received the Rosenhain Medal from the British Institute of Metals in 1954 and, in 1955, was elected Fellow of the Royal Society. In 1955 he was appointed deputy head of metallurgy div., Atomic Energy Research Establishment, Harwell, Berks., England. Since then, Dr. Cottrell has concentrated on the basic problems of physical metallurgy connected with the United Kingdom atomic power reactor program. The author of two books and some fifty papers, he has delivered outstanding lectures in various parts of the world and is planning a lecture tour of the United States this year.

M. GENSAMER

Maxwell Gensamer, Howe Memorial Lecturer for 1958, will receive a certificate, to be presented immediately before the Iron and Steel Division luncheon, on Tuesday, February 18. Maxwell Gensamer hails from Bradford, Pa., and was educated at the Carnegie Institute of Technology where he received his B.S. in metallurgical engineering in 1924, the M.Sc. degree in 1931 and the D.Sc. degree in 1933. His professional career intermingles with industry and the academic. He has served as acting metallurgist in charge of heat treatment for Page Steel & Wire Co., Monessen, Pa., professor of metallurgy at Carnegie Tech. in 1943, professor of metallurgy and head of the Dept. of Mineral Technology at Pennsylvania State University in 1945, assistant to the director of research, Carnegie-Illinois Steel Corp. in 1947, and in 1950 he joined the School of Mines, Columbia University as professor of metallurgy where he is at the present time. Professor Gensamer has been active in numerous metallurgical society affairs and similar activities which includes membership in the AIME, AAAS, ASM, British Iron & Steel Inst., Inst. of Metals, American Soc. for Engineering Education and has been a member of various committees concerned with National Defense for the National Research Council. He is the author of a book *Strength of Metals Under Combined Stresses,* as well as scores of technical articles.

Belgium To Be Host For Vacuum Congress

First International Congress on Vacuum Techniques will be held in Namur, Belgium, from June 10 to 13, 1958. This congress is officially sponsored by the Commissariat General of the Belgian Government with the Brussels 1958 International and Universal Exhibition.

The following main subjects will be treated: problems related to the scientific foundation of vacuum techniques; means of obtaining and measuring high and ultra-high vacua; applications of vacuum techniques in pure and applied research (namely in nuclear sciences and nuclear engineering); applications of vacuum techniques in metallurgy, chemical industry, pharmaceutical industry, plastic materials industry, electronic industry, optical industry, and food industry; and other subjects may be proposed.

Persons who wish to attend this congress or receive more detailed information may write to the President of the Executive Committee, *Professor E. Thomas, c/o CSN/ERM, 30 Avenue de la Renaissance, Brussels 4, Belgium.* Professor Thomas will send those requesting information a circular and questionnaire.

News of EDUCATION

► Dr. John C. Warner, president, Carnegie Institute of Technology, and Mr. Kenneth D. Mann, president, Firth Sterling Inc., announced the establishment of the Firth Sterling Chair of Metallurgical Engineering at Carnegie. Firth Sterling Inc., is a leading producer of tool and die steels, high speed steels, sintered tungsten carbides, high temperature alloys, super alloys, and zirconium. The appointment of this Chair greatly enlarges the scope of Firth Sterling's research activities, and at the same time, represents a gift by Firth Sterling to the $24,350,000 development program currently under way at Carnegie. The Chair will be occupied by Dr. Harold W. Paxton, assistant professor of metallurgical engineering and research metallurgical engineer in the Metals Research Laboratory at the Institute. Dr. Paxton joined the staff at C. I. T. in 1953. The author of numerous technical papers which have appeared in many metal publications, his current research interests are in the field of diffusion, corrosion, recrystallization, phase transformations and niobium alloys. Dr. Paxton is a member of the American Soc. for Metals, the AIME, the Iron and Steel Inst. and the Inst. of Metals. He is currently on the advisory committee on education for the ASM, and on the executive committee of the Society's Pittsburgh chapter. He is also a member of the publications committee, the Mathewson Award committee, and chairman of the physical metallurgy committee of the Inst. of Metals Div. of the AIME.

► Carnegie Institute of Technology has announced opportunities for graduate students in the College of Engineering & Science. Teaching assistantships, graduate fellowships and research assistantships for the academic year 1958-1959 are open in the fields of chemical, civil, electrical, mechanical and metallurgical engineering and in chemistry, physics, and mathematics.

A number of third-time and half-time teaching assistantships are available to graduate students in all departments of the college. Third-time teaching assistantships carry a stipend of $1200 plus tuition per academic year for the first year, and $1300 plus tuition for the second year. Half-time teaching assistantships carry a stipend of $1500 plus tuition per academic year for the first year and $1600 plus tuition for the second year.

A number of third-time and half-time research assistantships, under the supervision of a member of the staff, are available to graduate students in most departments of the college. There are some full-time research assistantships available to graduate students for two and one-half months in the summer.

Graduate fellowships, supported by outside agencies and special Institute funds, carrying grants ranging from $1200 to $2500, in addition to tuition, are offered by most departments in the college. In addition to the laboratories available in all departments, graduate students may work in close liaison with senior staff members in the Chemical and Petroleum Research Laboratory, the Coal Research Laboratory, the Metals Research Laboratory, and the Nuclear Research Center.

Requirements for advanced degrees, gradute courses and opportunities in research offered by the various departments, and other information, are described in the *Bulletin of Graduate Study in Engineering and Science*, sent free upon request.

Carnegie will consider applications from qualified students who wish to begin or return to graduate study in the fall of 1958. Applications for admission to graduate study and for assistantships or fellowships, together with transcripts or record

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Bylaw Changes

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Section 7. The term of office for officers shall be one year; for other members on the Society's Board of Directors three years; with the exception of a fourth Director serving for one year as described in Article V, Section 3*F*; and for Society representatives on the AIME Board of Directors, three years. All terms of office shall start at the close of the annual business meeting of AIME. *In the case of resignation or inability of any officer or director to act, or the election of a director as an officer of the Society, the Board of Directors of the Metallurgical Society shall appoint a successor to act until the next regular election when a successor will be nominated and elected to fill the unexpired term.*

Article VII

Committees

Section 4. The President shall appoint at the Annual Meeting of AIME a Finance Committee consisting of three of its members.

The Finance Committee shall prepare the annual budget, and examine, plan for, and submit recommendations concerning the financial condition and welfare of the Society for consideration of the Board of Directors. *The Treasurer of the Society shall be the Chairman or a member of the Finance Committee.*

All bills, accounts, and claims against the Society within the approved budget of the year shall be examined and approved by the *Treasurer* of the Society, or such officer or employe of the AIME as its Board of Directors shall from time to time designate.

Section 8. The Education Committee shall be appointed by the President. This Committee shall devise a program to promote high standards in the education of metallurgists and metallurgical engineers, the execution of which is subject to the approval of the Board of Directors. *The membership of the committee shall so far as possible equitably represent the membership of the various divisions of the Society.*

Article VIII

Nominations and Elections

Section 1.
Add.
e. The nominee for Treasurer of the Society.

ENGINEERING SOCIETIES PERSONNEL SERVICE, INC.

New York
8 West 40th St.

Chicago
84 East Randolph St.

Detroit
100 Farnsworth Ave.

San Francisco
57 Post St.

This placement service is sponsored by the Four Founder Societies for its members. Why not make use of it? It is operated as a non-profit organization. Applicants, if placed as a result of these listings, agree to pay a fee at the rates listed by the Service. All replies should be addressed to the key numbers indicated and mailed to the New York office. Please enclose six cents in postage to cover cost of mailing and return of application.

Two weekly bulletins of engineering positions open, one covering positions on the Pacific Coast and the other covering Mid-western and East Coast positions, are published and each is available to members at a subscription rate of $3.50 per quarter or $12.00 per annum, and to nonmembers at $4.50 per quarter of $14.00 per annum.

DON'T DELAY **REGISTER NOW**

AIME Staff, Board of Directors Honor Mrs. Ferry

The AIME Board of Directors took occasion on November 18 to honor Mrs. Grace Townsend Ferry, chief file clerk, upon her retirement from the Institute after 37 years of service. Shown, LEFT, shortly after the presentation of a gold watch by the Board of Directors are, left to right, Mrs. Ferry; Roger V. Pierce, Vice President; E. O. Kirkendall, Secretary; and Grover J. Holt, AIME President. RIGHT: Her fellow staff members held a luncheon for Mrs. Ferry on November 26 at which time they gave her a clock and a gold charm to commemorate the date. At the Luncheon are P. J. Apol, business manager; Mrs. Ferry; and Mr. Kirkendall.

Education

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and other supporting evidence, should be submitted as early as possible, not later than February 1, 1958. However applications from able and well qualified candidates will be considered at a later date. All inquiries should be addressed to: Dean of Graduate Studies, Carnegie Institute of Technology, Pittsburgh 13, Pa.

► Stanford University has recently announced the formation of a new Department of Metallurgical Engineering. Formerly, metallurgical activities were combined with those in mining and petroleum engineering in the Div. of Mineral Technology, School of Mineral Sciences. O. Cutler Shepard has been appointed executive head of this new department. However, since he is currently on leave, Professor Robert A. Huggins is acting executive head for the academic year 1957-1958.

During the last few years there has been a great increase in metallurgical activity at Stanford. A long-range program has been undertaken to interest high school students in this field, as well as to bring the opportunities in metallurgy to the attention of students currently enrolled in the university. As a result, there has been a very significant increase in the student body at both the undergraduate and graduate levels—the total enrollment having increased by a factor of five over the past five years.

In addition, an active graduate research program has been developed. Current research in the department includes work on diffusion kinetics in polyphase systems and systems in which a dispersed second phase is being formed. Programs are being undertaken to study the mechanisms by which dispersed phases affect creep behavior, and the effect of solute elements on the mechanical behavior of grain boundaries at elevated temperatures. A fundamental study of some of the factors that control the creep strength of brazed joints is also underway.

The curriculum has been extensively revised and enlarged. Its design is such that it is now possible for students to combine successfully their interests in metallurgy and any of several other fields. This is accomplished by requiring that all students take a common group of fundamental courses, and allowing them to supplement this core by one of several broad elective programs.

In order to accommodate these increased activities, considerable improvements have been made in the physical facilities of the Dept. of Metallurgical Engineering. Several valuable pieces of equipment have recently been acquired for use in teaching and research programs. These include a commercial vacuum melting and casting furnace, new X-ray diffraction spectrometer and fluorescence analysis equipment, and an additional induction heating unit.

Within the last few years over 2800 sq ft of laboratory space has been either newly constructed or completely renovated. These improvements raised the total laboratory space available to the department to over 13,000 sq ft not including classrooms and offices.

► The Minnesota School of Mines and Metallurgy, University of Minnesota, has been reorganized and now comprises three divisions: Mineral Engineering, Metallurgical Engineering, and the Mines Experiment Station. S. R. B. Cooke is head of the School and the three division chiefs are, respectively, E. P. Pfleider (on leave for the spring semester; D. H. Yardley is acting chief), S. R. B. Cooke, and H. H. Wade, appointed director of the Experiment Station.

Physical metallurgy has been transferred to the School of Chemistry where it will function as the Dept. of Metallurgy under M. E. Nicholson.

Separate curricula are now available in metallurgical engineering,

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Fourth Leo F. Reinartz Scholarship Competition

The fourth annual competition for the Leo F. Reinartz Freshman Scholarship was announced by the Carnegie Institute of Technology, Pittsburgh. The $700 scholarship award is made each year to a high school senior for study in the department of metallurgical engineering of Carnegie's College of Engineering. The scholarship, established in 1955 to encourage able young men to enter the field of metallurgical engineering, is currently held by Roy T. King of Ambridge, Pa. Other winners have been Donald McFarlane, Cleveland, and Larry E. Campbell of Pittsburgh. Funds for the scholarship are provided by the National Open Hearth Steel Committee of AIME to honor Leo F. Reinartz, vice president of the Armco Steel Corp. and an alumnus of Carnegie's department of metallurgical engineering, for his outstanding work with the Committee. Scholarship and admissions information may be obtained by writing to the Chairman of Admissions, Carnegie Institute of Technology, Pittsburgh 13, Pa. Applications must be made by January 15, for entrance in the freshman class of September, 1958.

Education

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geological engineering, mining engineering, and geophysics in the School of Mines and Metallurgy. Metallurgy is available in the School of Chemistry.

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► The following members were transferred to senior membership, effective Jan. 1, 1958: E. R. Weidlein, Pittsburgh; Normand E. LaMond, Short Hills, N. J. ; W. F. Evans, Chatham, N. J.; Roger L. Strobel, Salt Lake City; Arthur W. Gittins, Pittsburgh; and Daniel R. Hull, Waterbury, Conn.

► Membership Awards are to be continued during 1958. This consists of drawing from the members who have received Membership Awards during the year. The winner is to receive prepayment of five-years' dues and the four runner-ups, prepayment of one-year's dues.

► C. E. Birchenall has been appointed to succeed W. C. Ellis as the AIME representative on the board of directors of *Acta Metallurgica*. Dr. Ellis' term expired December 1957.

► The revised Bylaws of the Coal Division, SME, were approved.

► The revised Bylaws of the Mining, Geology, and Geophysics Division and name change were approved. Effective Feb. 18, 1958, this SME Division shall be known as the Mining and Exploration Division.

► Revised Bylaws of the Institute of Metals Division of The Metallurgical Society were approved with certain changes suggested by Secretary Kirkendall and the Board of Directors of The Metallurgical Society.

► An invitation to AIME to hold the 1967 Annual Meeting in Los Angeles was extended in a letter dated Oct. 8, 1957, by L. D. Jaffe, Chairman, Southern California Section, and D. G. Kingman, Chairman, Southern California Petroleum Section. The Board of Directors have expressed their appreciation of this courtesy and have directed Secretary Kirkendall to accept the invitation with the thanks of the Board.

► The Alfred Noble Prize for 1958 has been awarded to R. D. Bowerman, member of ASME, for his paper *The Design of Axial Flow Pumps*, which was published in ASME Transactions, Vol. 78, p. 1723, November 1956. The award was presented at the ASME Annual Banquet, Dec. 4, 1957, in New York.

► Approval was given for the establishment of the Knoxville Area Subsection of the Southeast Local Section, subject to a revision in the Bylaws to eliminate Article II, Section 2 of the bylaws submitted.

► The following were elected to Honorary Membership in AIME, by unanimous vote: Donald H. McLaughlin, C. H. Mathewson, and Fred Searls, Jr.

► Approval was given for the establishment of the Roswell Petroleum Section, subject to a few minor revisions in the bylaws.

► Approval was given for the establishment of the Snyder Local Section.

► Approval was given for the establishment of the Southwestern Society of Petroleum Engineers Student Chapter at Southwestern Louisiana Institute, Lafayette, La., subject to certain recommended changes in the bylaws.

► The following Citation in honor of J. F. Thompson, recipient of the 1958 Rand Gold Medal, was approved:

> "For his leadership of a mining and metallurgical enterprise which has contributed to free world strength; for administrative skills which have furthered the progress of the nickel industry; for his vision in stimulating scientific research; for demonstrating the value of a technical education combined with broad interests and human understanding."

► Staff changes announced at the November 18 Board of Directors meeting: John Cameron Fox became Assistant Secretary of AIME in addition to his position as Secretary of the Society of Mining Engineers. The appointment became effective November 18. As of Jan. 1, 1958, Donald R. Tone, formerly associate editor of MINING ENGINEERING, became assistant Secretary of SME.

1958 Blast Furnace Nominations

The nominating committee of the Blast Furnace, Coke Oven and Raw Materials Committee of the AIME recently placed in nomination the following people for the term starting in April 1958: chairman, James Duncan; vice chairman, Clarence Corban; secretary, Wilbert Huntley; director (4 yrs.) John Poast and Don Shattuck; and director (2 yrs.) J. B. Wagstaff.

Buffalo NOHC Meet Held in Ontario

The annual all-day off-the-record meeting of the Buffalo Section of the National Open Hearth Steel Committee was held in Hamilton, Ontario, on November 12. A near record crowd of 235 registered for the plant tour, technical sessions, and social functions. Featured in the morning was a plant tour of No. 2 and No. 3 O. H. Shops at the Steel Co. of Canada Ltd. The Steel Co. of Canada Ltd., is Canada's largest producer of steel. Its ingot production averages 2,1000,000 tons per year. About 9000 are employed at Hamilton.

After a luncheon at the Royal Connaught Hotel, courtesy of companies supplying the steel industry, the technical sessions were convened at the Royal Connaught Hotel. First on the program was a panel discussion on open hearth safety, led by Robert M. Jordan of the Lackawanna Plant of Bethlehem Steel Co., serving discussion leader.

Panelists were A. I. Gorman of the Steel Co. of Canada Ltd., Hamilton, Ontario; F. J. Todd, Republic Steel Corp., Buffalo; and J. Bingelman, Dominion Iron and Steel Co., Hamilton. Through the courtesy of the United States Steel Corp., their film, *The Germ*, was shown. This motion picture pointed out how during the war the necessity for producing steel in large quantity overshadowed quality considerations. Now, however, quality control is essential. This film has been used to help indoctrinate employees in making quality the prime factor in steel producing, and in recognizing the necessity of pleasing the steel companies ultimate boss—the customer. A prepared discussion on the motion picture was presented by George Newton of the Steel Co. of Canada Ltd.

The technical program was concluded with a discussion of elimination of bottom delays led by Robert M. Jordan of the Lackawanna Plant of Bethlehem Steel Co.

Following a cocktail hour, the Annual Banquet was held in the Crystal Ballroom of the Royal Connaught Hotel. John R. Atkinson, Buffalo Section chairman, and superintendent of steelmaking at Dominion Foundries and Steel Ltd., served as toastmaster. Both he and Harry A. Morlock, section secretary, and district sales manager, General Refractories Co., Buffalo, paid tribute to all who assisted in the plans for the day's activities. Special recognition went to Charles E. Moyer, section vice chairman, and open hearth superintendent, Republic Steel Corp., Buffalo, and to the members of the suppliers committee, Douglas Hollister, United States Graphite Co., and Robert R. Bowman, Harbison-Walker Refractories Co.

IMD Holds Annual Fall Meeting In Chicago

Shown clasping hands with Dr. Hibbard, Metallurgical Society President-Elect, were, (left to right) J. C. Kinnear, Jr., Metallurgical Society President, Ernest Kirkendall, AIME Secretary, W. R. Hibbard, Jr., Grover J. Holt, AIME President, and Augustus B. Kinzel, AIME President-Elect.

A multi-ring metallurgical circus was Chicago during the first week in November.

The Institute of Metals Division of the Metallurgical Society of AIME held its traditional Annual Fall Meeting at the Morrison Hotel. This year it was joined by the Iron and Steel Division, which concurrently held symposiums on steelmaking practices and continuous steelmaking.

Simultaneously, the Second World Metallurgical Congress was in session at a nearby hotel with 500 metallurgists from 40 countries, including the USSR, in attendance. At the International Ampitheatre, AIME members could see some 500 exhibits of the latest types of metallurgical equipment, furnaces, and metalworking machinery. Particular emphasis was given to ultrasonic testing equipment, vacuum furnaces, and some of the less common metals, such as berrylium, columbium, and tantalum.

The combined IMD-ISD session broke all previous attendance records with 1165 registrants, some 300 more than for 1956. This included a number of new AIME members.

The IMD High-Temperature Alloys Committee arranged a symposium on the *Relation of Structure and High-Temperature Properties.*

The Committee of Chemistry and Physics of Metals arranged two days of special sessions, one on the *Structure of Solid Solutions*, and a second on the *Science of Metal Hardening.*

The sixth annual Titanium Symposium was held with papers presented on *U. S. Progress in Titanium* and *European Progress in Titanium.*

A report was made by Dr. J. P. Nielsen on *Titanium in the USSR*, and a symposium was held on the *Manufacture and Use of Titanium.*

There was a symposium on *Uranium and Uranium Dioxide* and technical sessions on power metallurgy. One special evening meeting featured five papers presented by Russian metallurgists on ferrous and nonferrous metallurgical topics.

Above left: Seated at the dias during the IMD Meet were, (left to right) Don L. Clark, Augustus B. Kinzel, AIME President-Elect, H. B. Emerick, John Chipman, James Vannick, W. J. Harris, Jr., and Robert W. Shearman, Secretary-Treasurer of the Metallurgical Society. Below left: Other guests at the table were (left to right) T. D. Hess, Ernest Kirkendall, AIME Secretary, Bruce Gonser, Walter Dean, Robert Mehl, and Michael Tenenbaum. Above: Also sitting at the dais were (left to right) J. C. Kinnear, Metallurgical Society President, C. S. Smith, J. A. Wilson, the guest speaker, W. R. Hibbard, Jr., Metallurgical Society President-Elect, and AIME President, Grover J. Holt.

At the annual Fall Dinner of IMD, greetings were given by AIME President, Grover J. Holt. President-Elect Augustus B. Kinzel was also on the dais. President-Elect of the Metallurgical Society of AIME, Walter R. Hibbard, Jr., the present chairman of IMD, was toastmaster. Dinner guests were given a warm welcome by Michael Tenenbaum, chairman of the Chicago Section of AIME. J. C. Kinnear, Jr., President of the Metallurgical Society of AIME, told of progress achieved in organization since the Metallurgical Society of AIME was founded less than one year ago.

The Annual Fall dinner was addressed by John Albert Wilson, Andrew MacLeish Distinguished Service Professor of Egyptology of the University of Chicago. His subject was *Five Thousand Years of Modern Egypt*. From the history of ancient Egypt Dr. Wilson pointed out parallels in the psychology of Egypt under its present leadership and pointed to mistakes in past policy as well as desirable attitudes which might be taken in respect to the Arab countries today.

This may well have been one of the most important Annual Fall Meetings of IMD and certainly a cornerstone in the building of an ever-growing Metallurgical Society of AIME.

SOCIAL FUNCTIONS
THE METALLURGICAL SOCIETY OF AIME
1958 ANNUAL MEETING

Monday, February 17

12:00 noon	Welcoming Luncheon	Statler Hotel
6:00 pm	Pre-Smoker Cocktail Party	Statler Hotel
8:00 pm	Dinner-Smoker, Stag dinner and entertainment	

Tuesday, February 18

6:00 pm	The Metallurgical Society Social Hour	Sheraton-McAlpin Hotel
7:00 pm	The Metallurgical Society Annual Dinner	Sheraton-McAlpin Hotel
9:00 pm	AIME Informal Dance	Statler Hotel

Wednesday, February 19

7:00 pm	Annual AIME Banquet and President's Reception	Waldorf-Astoria Hotel

Indian Engineer Group Guests at Pittsburgh Meeting

The hospitality and friendliness of the Pittsburgh Section fostered the good will of 42 young Indian engineers, who were guests at the Section's Off-the-Record Meeting on November 1, at the Penn-Sheraton Hotel, Pittsburgh. The young men are part of a contingent of *IN STEP*, a training program designed to show 200 of India's young graduate engineers the methods by which United States steel companies operate by providing them with a year's on-the-job training and classroom instruction. This vital project is called the *Indian Steel Training and Educational Program*, whose initials form the words *IN STEP*.

The task of industrialization undertaken through India's Second Five Year Plan is an enormous one. In a nation of nearly 400 million people there are only three steel plants in all, and only two of appreciable size. As part of her plan for further expansion the government is financing three new steel plants with a combined capacity of 3 million tons. To this end India is faced with a growing need of sufficient technically trained men with the skill and experience to work in vital supervisory capacities. As an aid in solving this problem, *IN STEP* was inaugurated to cement better Indian-American relations and to provide potential Indian industrial leaders with an invaluable practical training.

The young engineers carefully selected for this program are chosen by the Indian Government after close examination of their aptitude for training, personal suitability, competence in English and physical health. Before leaving for America each man had been guaranteed a specific job in one of the new plants and each had pledged himself to a minimum of five years' work in steel upon his return. Working a regular eight-hour shift, the in-plant instruction for each engineer consists of general observation of all steelmaking processes. But essentially each student is engaged in specific operations preparing him for the job he will assume when he returns to India.

Professor M. S. Sundaram, Cultural Counselor of the Embassy of India, was the timely guest speaker at the Fellowship Dinner held in the Ballroom. D. L. McBride, U. S. Steel Corp., served as toastmaster and presented awards to several members. J. T. Brown was honored for having completed fifty years as a member of the AIME. William J. Babcock, a graduate student at the Carnegie Institute of Technology, was chosen for the best Student Paper Award. His subject was *Relation Among The Grain Boundary Area, Twin Boundary Area and Hardness of Recrystallized Cartridge Brass*. The Frank L. Toy award for outstanding work in the field of metallurgy was presented to J. H. Richards, head of the process metallurgy div., U. S. Steel Corp.

Preceding the dinner, technical sessions were held by the five subdivisions of the Section, namely the Coal Div., Petroleum Subsection, Institute of Metals Group, Minerals and Metals Economic Committee, and the National Open Hearth Steel Committee. The day long sessions featured discussions on the technical, safety, and operating advances in the separate fields, as well as the presentation of thirty-seven papers by leading engineers from various industries.

Eight hundred and fifty engineers participated in the Meeting as well as a host of one hundred three students from local colleges and universities.

Pacific Southwest Minerals Conference To Be Held in March

Sponsored by the AIME San Francisco Section, the 1958 Pacific Southwest Minerals Industry Conference will be held at the Hotel St. Francis in San Francisco on March 27 to 29.

Fred Lohse, general chairman, reports that the first regional conference, held in Reno last April, established a standard of excellence that will be a challenge to surpass. The committee this year expects to put the emphasis during the meeting on youth with the hope that many of the junior men in the mineral industries in the region will be given an opportunity to attend, along with their wives. Plans now include presentation by men in the 35 to 45 age bracket of most of the papers at the meeting.

Included on the program will probably be papers by the younger men in the chemical and process industries in the Southwest region. The aim in scheduling such papers is to give industrial minerals producers a better insight into the production problems, especially the specification requirements and the general exploitation of the mineral materials which are supplied to the chemical and process industries.

Program chairman is J. K. Brooke, Kaiser Aluminum & Chemical Corp., Oakland, Calif. Further plans for the Conference will be announced in forthcoming issues of JOURNAL OF METALS.

Engineering Who's Who Now In Preparation

Over 4000 AIME members will soon receive requests for biographical sketches from the publishers of *Who's Who in Engineering*—the *Lewis Historical Publishing Co.* Edward H. Robie is the AIME representative on the EJC task committee which is cooperating with the publisher to make the volume as complete as possible. With the cooperation of the Secretaries of the three AIME Societies, he has carefully checked the names of those who qualify from the last directory. Some have been missed because their title is not indicated or they lack some of the qualifications. The publisher has stated that the purchase or nonpurchase of the volume has no bearing on inclusion of one's name, though the purchase will be solicited to meet the cost of the book.

Around the Sections

• The **Boston Section** met on October 7, at the Massachusetts Institute of Technology Faculty Club, Cambridge, Mass., for dinner. The guest speaker was William Dyrkacz, who is associated with the Allegheny Ludlum Steel Corp. at Watervliet, N. Y. He spoke on *Vacuum Processes in Steelmaking*, emphasizing the development of very large vacuum consumable-electrode melting units.

On November 4, the Section met at the MIT Faculty Club, Cambridge, and enjoyed a film presentation *Mining for Nickel*, produced by the International Nickel Co. After the movie, the featured speaker, Anthony Werner, School of Industrial Management, MIT, talked on *Mining and Prospecting*.

The third meeting of the Section, President's Night, was held on December 2, at the MIT Faculty Club. Grover J. Holt, President of AIME, was the after-dinner speaker. He gave a short talk on the changes in AIME organization which have taken place recently, followed by a short discussion on the trends in beneficiation of iron ores which he has pioneered and which he has seen come to fruitation in recent years.

• The fall meeting of the **Oregon Section** was held on September 20, at Burns Restaurant, Portland, Ore. The bill featured a film showing of *Mining Cobalt in Katanga* from the Battelle Memorial Institute, Columbus, Ohio.

The Section met on October 18, in Albany, Ore., and toured the Bureau of Mines laboratories, the Oregon Metallurgical Co.'s plant, and the Wah Chang's facilities on the Bureau of Mines grounds. A social and dinner was later held at the Albany Hotel and the topic, *History of Scrap Iron*, was the featured talk. given by Alva H. Roberson, acting chief for the Div. of Minerals Technology, Region 1, USBM.

On November 15, the Section held a meeting at Burns Restaurant, Portland. L. W. Meyer, assistant works manager, fabricating division, Vancouver plant, Aluminum Co. of America, was the guest speaker. He discussed *A Gringo Looks at Changing Mexico*. Earlier in the day, the Section featured a Ladies Get-Acquainted Luncheon at Davey's Locker, Portland.

• November 14, was President's Night of the **Cleveland Section**, held at the Carter Hotel, Cleveland. After the reception and dinner, Grover J. Holt, AIME President, was the principal speaker. He spoke on *The New Look of AIME for 1957*. Also featured as a guest speaker was Rev. Laurence Hall, Rector of St. Paul's Episcopal Church, East Cleveland, who gave an amusing talk, *Humor—A Resource*.

• A joint dinner meeting was held by the **NOHC Western Section** with the Metallurgical Society of the **Southern California Section** of AIME, on November 27, at Rodger Young Auditorium, Los Angeles. The featured speakers were N. E. Allen of the National Physical Laboratories in Teddington, England, and C. Crussard of the French Iron & Steel Institute, who spoke jointly on the metallurgical research in their respective countries.

• The **St. Louis Section** held a meeting on October 11, at Cave in Rock State Park, near Cave in Rock, Ill. A field trip was featured through the mines and mills of Minerva Oil Co., Alcoa, and Ozark-Mahoning Co. with guides selected according to the interests of each party. Hosts for the trip were the operators in the Illinois-Kentucky Fluorspar District under the chairmanship of Gill Montgomery, Minerva Oil Co. Buffet lunch was served. Later, a business meeting was held in the park after a fish fry in the evening. The nominating committee made its report for officers for 1958. They are: chairman; G. Donald Emigh; vice chairman, Gill Montgomery; secretary-treasurer, Gordon M. Bell; and assistant secretary-treasurer, Norman S. Geist.

On November 8, the Section met at the Hotel York, St. Louis, for a dinner-meeting. Andrew Robertson, managing director, Eastern Smelting & Refining Co., was the guest speaker. He gave a talk covering a description of his company's smelter at Chicoutimi, Quebec, and the governing factors in selecting the site which will supply the raw material. Robertson illustrated his discussion with a slide presentation.

December 13 was Ladies Night at the Section, featuring Washburn Shipton of Washington University as the principal speaker. He presented an illustrated slide lecture, *Diamonds*.

• The **Pittsburgh Section** met on November 20, for dinner at the Park Schenley Restaurant, Pittsburgh. The featured speaker, Elmer W. Pehrson, chief, division of foreign activities, U. S. Bureau of Mines, Washington, D. C., discussed *Asia and its Mineral Industries*. He based the talk on his recent extensive trip to the East and Middle East, which comprised 26 countries. Mr. Pehrson's presentation, which was illustrated with color sides, dealt with the Jewish and Arabian situation, suckers, oil, and the many other problems in this tense and important part of the world.

• More than 200 AIME members attended the **Southeastern Section's** two day session at the Andrew John-

Around the Sections

(Continued from page 56)

son Hotel, Knoxville, Tenn., on September 27. The convention featured a survey of the mining program at Sunbright, Va., where high grade magnesium limestone is produced for use by the AEC. A. J. McDonnell, plant manager of Foote Mineral Co. at Sunbright, gave a discussion on the project. Donald J. Belcher, president of the Donald J. Belcher & Associates Inc., Ithaca, N. Y., spoke on the expeditious use of aerial photography in locating new mineral ranges. Fred W. Drosten, section head of titanium sponge development of Carmet Corp., Chattanooga, presented a talk on *Titanium Production*. *Some Heavy Mineral Exploration Techniques* was the subject of John F. Lord, chief placer engineer for American Smelting & Refining Co., which has an office in Knoxville. Mr. Lord told of explorations at sea off the Florida coast. K. B. Brown of Oak Ridge National Laboratory discussed *Solvent Extraction Processes in the Hydrometallurgical Treatment of Ores*. Other featured speakers at the convention were William Black, manager, American Zinc Co. of Tennessee, Mascot; and R. E. Samson, American Limestone Co. A field trip through the Young Mine at Mascot and the Oak Ridge Laboratory topped off the second day's session.

• The **Washington, D. C. Section** met for cocktails and dinner on November 12, at the Cosmos Club, Washington, D. C. F. R. Morral of the Cobalt Information Center, Battelle Memorial Institute, Columbus, Ohio, was the guest speaker. He presented a 20-min talk on the metal cobalt augmented with a movie depicting production of cobalt in Katanga. The film covered the production of cobalt in the Belgian Congo through mining, concentration, refining, and reduction to the elemental metal.

• Project director of project *Vangard* of the U. S. Naval Research Laboratory, Washington, D. C., John Hagan addressed the **Columbus Section**, October 10, at a dinner meeting at Grandview Inn, Columbus, Ohio. He spoke on *The Space Satellite*.

Shown above are Gilbert L. Cox (left), chairman of the Niagara Frontier Section and Grover J. Holt (center), AIME President, as they presented the second annual Frank J. Tone Medal to Clifford C. Furnas (right), University of Buffalo Chancellor, for outstanding achievements in the field of metallurgy and related sciences, at the November 21, meeting of the Niagara Frontier Section in the Hotel Stuyvesant, Buffalo. Shown at left is the medal.

The University Extension, University of California, Educational Sales Dept., recently released *Making A Work Sampling Study*, **a 23-min educational 16-mm sound, color, black and white film, sale price: color $195; black and white $110. The movie is designed to create a better understanding of some of the problems of management and methods of solving them. This film study covers: definition of the problem, preparatory steps, designing the study, making the observations, analyzing and summarizing the data, and reporting the results. Of great value to business and management, the film may be obtained from the following addresses of the sales department: Los Angeles Campus, 10851 Le Conte Ave., Los Angeles 24, and downtown Los Angeles, 813 S. Hill St., Los Angeles 14.**

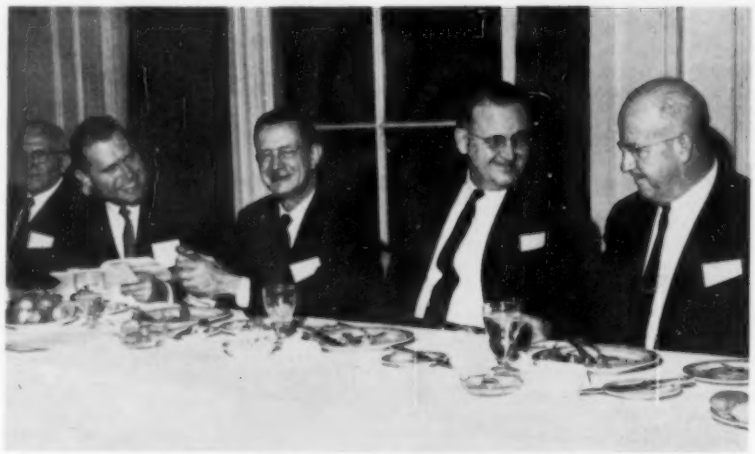
A booklet describing 14 new 16-mm color-sound motion pictures is now available free from the *Colorado Fuel and Iron Corp.*, **P.O. Box 1920, Denver 2, Colo. The films listed are offered on a free loan basis to schools, libraries, television stations, and civic and business organizations. Four of the motion pictures belong to the "Indian Paint" series that describe the first discovery of iron ore by the American Indian who used the powdered ore for face paint. The scene then shifts to modern steelmaking operations, with dramatic photos of blast furnaces and open hearths. Each of these four films depict the production of a single major steel product: rails, wire rope, grader blades, and chain link fence. Other motion pictures included in the catalog are:** *Reinforced for Life*, **20 min—the story of concrete and how it can be made infinitely stronger when reinforced with welded wire fabric;** *Know Your Ropes*, **30 min—a technical film on the manufacture, construction, and application of industrial wire rope;** *Changing the Face of the Earth*, **20 min—the manufacture of grader blades from basic steel to finished product; spectacular scenes of earth-moving equipment in action;** *Farmer Brown—Steel Worker*, **30 min—a review of the many steel products now used on the modern farm and ranch;** *Steel's Party*, **38 min—a complete survey of the use of steel on the farm;** *Quality Unlimited*, **30 min—how wire rope is manufactured and inspected;** *Another Step Forward*, **20 min—a technical description of "Lectro-Clad" nickel plating on steel for corrosion resistance and other applications;** *Navajo Number One*, **the production of seamless oil well casing and tubing and its installation at an actual well;** *How To Get Ahead*, **15 min—the manufacture of high-pressure heads for industrial tanks; and** *Make Mine Safety*, **20 min—how mine rock bolts are manufactured and their application in three western mines.**

PERSONALS

Edgar C. Bain, assistant executive vice president-operations, for United States Steel Corp., retired after nearly 30 years of service with the corporation. A graduate of Ohio State University, Dr. Bain contributed immeasurably to the field of steel heat treatment and to the development of new methods of measurement. He recieved the AIME Robert W. Hunt Medal for his work in the field of Fe-Cr-Ni alloys in 1929 and was the recipient of the Henry Marion Howe Medal of the American Soc. for Steel Treating, two years later, for his studies on the grain structure of martensite. In 1934, Dr. Bain was awarded the American Iron & Steel Inst. Medal for his paper *Some Characteristics Common to Carbon and Alloy Steels.* Lehigh University conferred on him the honorary degree of doctor of chemical engineering in 1936. In 1937, Ohio State University awarded him the Benjamin C. Lamme Medal for *Eminence in Engineering,* and in that same year he served as president of ASM. He received the Society's Albert Sauveur Achievement Award in 1946 and two years later was given a Distinguished Service Award for Meritorious Contributions to Progress in Alloy Steels. In 1954 Dr. Bain was the recipient of the Grand Medal of the Societe Francaise de Metallurgie in Paris, France. The author of some 40 technical papers and several technical books, Dr. Bain discovered "bainite" which was named in his honor. He was also honored when one of the major buildings of U. S. Steel's Research Center in Monroeville, Pa., was named the Edgar C. Bain Laboratory of Fundamental Research.

Ernest M. Goldstein has joined Metal & Thermit Corp., Rahway, N J., as head of the metallurgical laboratory. He was formerly associated with the Nickel Processing Co. in Montclair, N. J.

Frank T. Sisco, director of the Engineering Foundation, is the first chairman of the new ASM Metallurgical Documentation Committee. This committee will have responsibility for advising and coordinating all activities of ASM in the fields of abstracting, literature classification and searching, and bibliographic services. Mr. Sisco far many years was editorial director of Alloys of Iron Research. When he became director of Engineering Foundation in 1949, his work on manuscripts for Alloys of Iron monographs was turned over to Mrs. Sisco who had been assistant editor for the project since its inception in 1930. Other members of the new ASM committee are: **Wallace R. Brode,** National Bureau of Standards; **Dolph G. Ebeling,** General Electric Co.; **Herman Henkle,** John Crear Library; **D. C. Hilty,** Electro Metallurgical Co.; **Irving H. Jenks,** Aluminium Laboratories Ltd.; **George A. Roberts,** Vanadium-Alloys Steel Co.; **Amos J. Shaler,** The Pennsylvania State University; **John W. W. Sullivan,** AISI; **E. E. Thum,** *Metal Progress;* and **Marjorie R. Hyslop,** ASM.



Pictured at the reunion banquet celebrating the 25th anniversary of the Metals Research Laboratory of Carnegie Institute of Technology, Pittsburgh, on Oct. 24, 1957, was Robert F. Mehl (center), director of the Laboratory and head of the Dept. of Metallurgical Engineering. Others pictured include (left to right): Edgar C. Bain, retired vice president of U. S. Steel Corp., the guest speaker; George Roberts, vice president of Vanadium-Alloys Steel Co., toastmaster; Dr. Mehl; B. Richard Teare, dean of the College of Engineering and Science; and Walter Blenko, chairman, executive committee, Carnegie Institute of Technology.

Porter H. Brace has been appointed assistant professor of physics at Illinois Wesleyan University. He was previously consulting metallurgist with Westinghouse Research Laboratories, Pittsburgh.

J. L. Lamont is now manager of the technical services group of the Metals Research Laboratories, Niagara Falls, N. Y., which serves the Electro Metallurgical Co., division of Union Carbide Corp. He joined Union Carbide in 1929.

K. P. Campbell has been promoted to general superintendent of operations of the Sheffield Div., Armco Steel Corp., Houston.

Frederick Nims Rhines, professor of light metals at Carnegie Institute of Technology, Pittsburgh, was presented the Henry Marion Howe Medal at the ASM annual 39th National Metals Exposition and Congress held at Chicago on November 2 through 8. The citation was awarded for a paper entitled *Grain Boundary Creep in Aluminum Bicrystals,* which was published in the 1956 *Transactions* of the ASM under the authorship of F. N. Rhines, W. E. Bond and M. A. Kissel.

Paul D. Frost, a specialist in light metals research at Battelle Memorial Institute, Columbus, Ohio, was awarded the 1957 Metal Testing Institute Achievement Award for his article concerning heat treatment of titanium and a subsequent lecture based on the article. The award was presented by Howard N. Bosworth, president of the Metal Treating Institute at the MTI annual meeting in Chicago. Mr. Frost is chief of Battelle's Light Metals Div.

T.D. De Souza Santos, past president of the Associacão Brasileira de Metais, and head of the extractive metallurgy branch of the Instituto de Pesquisas Tecnológicas, São Paulo, Brazil, has been appointed professor catedrático of nonferrous production metallurgy at the Escola Politecnica of the São Paulo University. His thesis *A New Process for the Treatment of Parkes' Crusts* dealt with the experimental part of the process developed at the Instituto de Pesquisas Tecnológicas.

Charles T. Stott, formerly assistant general manager the Sparrows Point plant of Bethlehem Steel Co., Sparrows Point, was recently promoted to general manager of the steel plant.

Kenneth F. Waggener has been named assistant superintendent of Republic Steel Corp.'s bessemer rolling and finishing mills at Youngstown. F. A. Court will succeed Waggener as assistant superintendent of bessemer converters.

John W. McCredie, previously sales manager of the refractories division of the McLain Fire Brick Div., H.K. Porter Co. Inc., Pittsburgh, is now affiliated with the Refractory Special-

(Continued on page 59)

ties Co., Philadelphia, as sales representative with headquarters in Chicago.

George P. Hansen, assistant vice president in charge of steel plants of Wheeling Steel Corp., retired on Oct. 1, 1957 after 16 years service with the company. Mr. Hansen has been affiliated with the iron and steel industry throughout his entire career and will continue in his retirement as a consultant.

Robert B. Gordon has been appointed project engineer in charge of component development for the Sheldon Nuclear Facility by the Atomics International Div. of North American Aviation Inc., Canoga Park, Calif. He was previously associated with the Bettis Atomic Power Div. of Westinghouse Electric Corp., Pittsburgh, as manager, core engineering dept.

H. C. Chang was recently appointed advisory engineer for the Solid State Electronics Development Section of the Materials Engineering Dept. at Westinghouse Electric Corp. in East Pittsburgh.

OBITUARIES

Andrew Lesko, III (Member 1949), passed away on Oct. 19, 1957 in Palmerton, Pa., after a long illness. Born in Allentown, Pa., on Dec. 10, 1916, he had served The New Jersey Zinc Co. (of Pa.) as a technician in the research division. Mr. Lesko was with the company for 21 years.

Carlton G. Lutts (Member 1918) died recently in Salem, Mass. The noted naval engineer was born at Malden, Mass., on Feb. 21, 1891, and was a graduate of the University of Maine. Dr. Lutts was co-inventor of the Di-Lok anchor chain, now standard equipment on all Naval ships and most commercial liners. He also developed the method for industrial radiographs of heavy ship castings. A recognized authority on the manufacture of chain and rope, he was twice commended by the Navy Dept., and also awarded the Navy's Meritorious Civilian Service Award. Dr. Lutts was the first president, Boston Section, of the Soc. for Nondestructive Testing Inc., and a member of the American Soc. for Testing Materials, American Chemical Soc., and AIME.

William C. Thompson (Member 1952) passed away in Pittsburgh on Oct. 22, 1957. He was born in McKeesport, Pa., on July 19, 1896, and studied five years at the Carnegie Institute of Technology. Prior to his death, Mr. Thompson had been long associated with the A.P. Green Fire Brick Co., Pittsburgh office, as the company's special representative on refractories to the steel industry.

Memorial Resolution

PAUL DYER MERICA

WHEREAS, with the passing of Dr. Paul Dyer Merica on the 20th of October, 1957, in Tarrytown, N. Y., the Institute has lost one of its most loyal and distinguished members, and

WHEREAS, during his nearly 40 years of membership he served the Institute in a variety of capacities, including 12 years as Vice-President, and in 1942 was awarded Honorary Membership in the Institute, and

WHEREAS, during his professional life he made great contributions to the art of metallurgy, including his theory of the precipitation hardening of metals and alloys for which contribution he received the James Douglas Medal in 1929, the John Fritz Medal in 1938, the Institute of Metals Medal (Great Britain) in 1941, the Franklin Institute Medal in 1942 and the American Society for Metals Gold Medal in 1951, and Honorary Degrees of Doctor of Science from the Depauw University, Lehigh University and Stevens Institute of Technology,

WHEREAS, both in his profession and in his association with the International Nickel Company of Canada Limited, of which he was President at the time of his retirement, he contributed throughout his life to the maintaining of the highest professional standards coupled with a personal character of the highest rank and a humanity which endeared him to all of his associates,

THEREFORE, BE IT RESOLVED, the American Institute of Mining, Metallurgical, and Petroleum Engineers records with deep sorrow the loss of this valued Member and friend; and

BE IT FURTHER RESOLVED, that this Resolution be spread upon the Minutes of this meeting and a copy be sent to Dr. Merica's mother.

Ernest Kirkendall
Secretary AIME

November 18, 1957

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Oct. 31, 1957, was 28,492; in addition 3,343 Student Members were enrolled.

ADMISSIONS COMMITTEE

Harold K. Work, Chairman; Francis B. Foley; T. D. Jones; E. S. Machlin; J. H. Scaff; Paul Von Stein; T. B. Winkler.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Kenneth G. Carroll, Summit, N. J.
Y. T. Chou, Pittsburgh
Donald E. Cooper, Las Vegas, Nev.
Russell S. Condiff, Gary
Thomas P. Greaney, Hammond, Ind.
Wasyly Hodlewsky, Milwaukee
N. S. Rajan, Urbana, Ill.
Robert W. Smith, Crown Point, Ind.
Lawrence A. Swick, Madison Hts., Mich.
Witold Dowoyna Sylwestrowicz, Murray Hill, N. J.
P. G. Thornhill, Falconbridge, Ont., Canada
Edward D. Weisert, Niagara Falls, N. Y.

Associate Members

Elmer A. Carlson, Hinsdale, Ill.
Herbert E. Freier, St. Paul
Charles A. Gillan, Jr., Springfield, Pa.
Milton O. Gold, Sandy, Utah
W. M. Jarnagin, Strasburg, Va.
A. Richard Moore, Cleveland
Rolston W. Topping, Phoenix, Ariz.
D. R. Wiles, Vancouver, B. C., Canada

Junior Members

Bernard Brodwin, Brooklyn
F. R. Charvat, Niagara Falls, N. Y.
George B. Cherniack, Niagara Falls, N. Y.
Robert Lewis Dreshfield, Rolla, Mo.
John J. Herr, Little Ferry, N. J.
Edward J. Jablonowski, Columbus, Ohio
Lowell H. McCarter, Hammond, Ind.
Peter Moanfeldt, Niagara Falls, N. Y.
John P. Page, Wright-Patterson Air Force Base, Ohio
Robert W. Ray, Chicago
Wallace F. Sheely, Niagara Falls, N. Y.
Russell A. Snyder, Munster, Ind.
David A. Stevenston, Cambridge, Mass.
F. M. Yans, Brookline, Mass.

CHANGE OF STATUS

Associate to Member

William A. Greene, East Chicago, Ill.

REINSTATEMENTS—CHANGE OF STATUS

Junior to Member

Daniel J. Maykuth, Columbus, Ohio
Thomas D. Olson, Worcester, Mass.
E. Rabeau, Copper Cliff, Ont., Canada

Student to Member

George P. Dahm, Linden, N. J.

Student to Associate

Floyd E. Joyce, St. Paul

NECROLOGY

Date Elected	Name	Date of Death
1936	George O. Argall	Oct. 17, 1957
1917	John W. Austin	Nov. 22, 1957
1941	Perry L. Charles	Oct. 19, 1957
1954	D. E. Coughlin	Oct. 25, 1957
1909	Erle V. Daveler Honorary Member	Nov. 11, 1957
1910	Carl F. Dietz	Oct. 4, 1957
1904	F. W. Guernsey Legion of Honor	Nov. 1, 1957
1901	L. F. S. Holland Legion of Honor	Nov. 13, 1957
1949	Andrew Lesko, III	Oct. 19, 1957
1918	Carlton G. Lutts	Unknown
1914	Frederick MacCoy	Oct. 14, 1957
1892	Thomas Robins Legion of Honor	Nov. 4, 1957
1903	LeRoy Salsich Legion of Honor	Oct. 26, 1957
1891	Charles Henry Snow Legion of Honor	Oct. 28, 1957
1935	J. W. Stewart	Unknown
1956	Martin S. Taylor	Sept. 8, 1957
1952	W. C. Thompson	Oct. 22, 1957

Annual Meeting Program

The Metallurgical Society of AIME

February 16 to 20, 1958, Sheraton-McAlpin Hotel

SATURDAY, FEBRUARY 15, PM

Met Soc

Board of Directors Meeting

2:00 pm Sheraton-McAlpin Hotel Parlor F
J. C. Kinnear, Jr., *President*

SUNDAY, FEBRUARY 16, AM

Met Soc

Publications Committee Meeting

10:00 am Sheraton-McAlpin Hotel Parlor F
J. S. Smart, Jr., *Chairman*

SUNDAY, FEBRUARY 16, PM

Met Soc

Metallurgical Manpower Symposium

2:00 pm Sheraton-McAlpin Hotel Red Room
Morris Cohen and David Swan, *Associate Chairmen*
Scientific Brainpower—Are We Solving the Problem?: *H. A. Meyerhoff*, Scientific Manpower Commission.
Report of Special Committee on Manpower for the Metallurgy and Ceramics Profession:
(1) Introduction: Committee History and Organization: *G. A. Roberts*, Vanadium-Alloys Steel Co.
(2) Pre-College Student Awareness of our Profession: *W. R. Hibbard, Jr.*, General Electric Co.
(3) Adult Awareness of our Profession; A Proposed Scholarship Program: *W. E. Mahin*, Malleable Research and Development Foundation.
(4) Program for Action: The Metallurgy-Ceramics Foundation: *G. A. Roberts*, Vanadium-Alloys Steel Co.

Council of Education

Social Hour

5:00 pm Statler Hotel Georgian Room

Council of Education

Buffet Dinner

6:00 pm Statler Hotel Georgian Room

Council of Education

Technical Session

8:00 pm Gold Ballroom
J. C. Calhoun, Jr., and Koehler Stout, *Associate Chairmen*

TUESDAY, FEBRUARY 18, PM

All-Institute

Technical Session

2:00 pm Statler Hotel Grand Ballroom
Speaker: Colonel C. D. Patterson, Chief, Department of Army Staff, Headquarters, Army Ballistics Missile Agency, Redstone Arsenal, Alabama

All-Institute

Annual Business Meeting

4:00 pm Statler Hotel Grand Ballroom

Met Soc **Social Hour**

6:00 pm Sheraton-McAlpin Hotel Winter Garden
(Cocktails available)

Met Soc **Annual Dinner**

7:00 pm Sheraton-McAlpin Hotel Ballroom
J. C. Kinnear, Jr., *President*
Speaker: Harold Eide
Subject: *My Alaska Adventures*

THURSDAY, FEBRUARY 20, AM

Met Soc

Board of Directors Breakfast Meeting

8:30 am Sheraton-McAlpin Hotel Parlor E
J. C. Kinnear, Jr., *President*

Extractive Metallurgy Division

MONDAY, FEBRUARY 17, AM

EMD

Refractories and Some of the Atomic Age Metals

10:00 am Sheraton-McAlpin Hotel Green Room
A. P. Thompson and A. E. Fitzgerald, *Associate Chairmen*

Refractory Usage in Titanium and Zirconium Metallurgy: *A. H. Roberson*, U. S. Bureau of Mines.
Usage of Refractories in Vacuum Metallurgy: *P. J. Clough*, National Research Corp.
Cerium Monosulfide, a Unique Refractory: *L. M. Litz*, National Carbon Co.

EMD **Copper**

10:00 am Sheraton-McAlpin Hotel Red Room
W. L. Brytczuk and H. K. Spaulding, *Associate Chairmen*

Flash Smelting of Copper Concentrates: *P. Bryk, J. Ryselin, J. Honkasalo, and R. Malmstrom*, Outokumpu Oy, Helsinki, Finland.
Economics of Direct Reverberatory Smelting as Compared to Roasting and Smelting: *R. J. Stevens*, Kennecott Copper Corp.
Reverberatory Smelting of Chuquicamata, Chile: *George Morris*, Chile Exploration Co., Chuquicamata, Chile.

MONDAY, FEBRUARY 17, PM

EMD **Copper and Refractories**

2:30 pm Sheraton-McAlpin Hotel Red Room
H. Winn and George Morris, *Associate Chairmen*

Mechanical Tuyere Punching of Copper Converters: *D. A. Kinneburg and B. T. Berge*, Kennecott Copper Corp.
Heat Flow and Temperature Distribution Around a Copper Converter Tuyere: *W. A. Krivsky*, Electro Metallurgical Co., Div. Union Carbide Corp., and *R. Schuhmann, Jr.*, Purdue University.
A Study of Mineral Composition of Basic Brick After

Service in Copper Converters: *C. B. Clark and J. S. McDowell*, Harbison-Walker Refractories Co.

Basic Roof in Wire Bar Refining Furnace: *J. Towers and R. Brown*, U. S. Metals Refining Co.

Suspended Basic Roof on a Cold-Charged Copper Anode Furnace: *G. Bridgstock*, Canadian Copper Refiners Ltd.

EMD
Rare Earths and Miscellaneous Metals

2:30 pm Sheraton-McAlpin Hotel Green Room

R. A. Lubker and L. W. Coffer, *Associate Chairmen*

Effect of Amine Complexing Agents in the Separation of Rare Earths: *W. G. Gruzensky and G. T. Engel*, U. S. Bureau of Mines.

Separation of Rare Earths by Ion Exchange: *F. H. Spedding and J. E. Powell*, Iowa State College.

Availability, Recovery, and Properties of Rhenium Metal: *D. M. Rosenbaum and I. E. Campbell*, Battelle Memorial Institute.

Beryllium Production by Chloride Extraction and Reduction: *W. W. Beaver*, Brush Beryllium Co.

Preparation of Anhydrous Chlorides of Cerium and Thorium: *R. Didchenko*, National Carbon Co.

TUESDAY, FEBRUARY 18, AM

EMD
Executive Committee Breakfast Meeting

7:30 am Sheraton-McAlpin Hotel Parlor E

B. W. Gonser, *Chairman*

EMD Titanium

9:00 am Sheraton-McAlpin Hotel Green Room

W. A. Krivsky and D. H. Baker, Jr., *Associate Chairmen*

Effect of Additions on the Chlorination of Metal Oxides by Calcium Chloride: *N. F. Neumann and A. W. Schlechten*, Missouri School of Mines.

Chlorination of Titanium Slags: *E. C. Perkins*, U. S. Bureau of Mines.

High-Temperature Chlorination of TiO_2-Bearing Minerals: *W. E. Dunn, Jr.*, E. I. duPont de Nemours and Co.

Rates of Reaction of Oxygen, Nitrogen, and Carbon Monoxide With Sodium-Titanium-Chloride Melts: *L. W. Gendvil and O. W. Moles*, National Lead Co.

Electrorefining of Titanium From Specially Prepared Ternary Alloys: *D. H. Baker, Jr., J. R. Nettle, and T. E. Hill, Jr.*, U. S. Bureau of Mines.

EMD Zinc, Bismuth, and Cadmium

9:00 am Sheraton-McAlpin Hotel Red Room

H. R. Bianco and T. I. Moore, *Associate Chairmen*

Bismuth Recovery at Oroya: *W. C. Smith and P. J. Hickey*, Cerro de Pasco Corp.

Improved Weaton-Vacuum Zinc Condenser: *H. K. Najarian*, St. Joseph Lead Co.

Removal of Magnesia and Lime From Dolomitic-Type Zinc Concentrates: *W. Schmittroth*, The Bunker Hill Co.

Recovery and Production of Cadmium at the Great Falls Plant of The Anaconda Co.: *A. I. Alf*, The Anaconda Co.

WEDNESDAY, FEBRUARY 19, AM

EMD
Committee Chairmen Breakfast Meeting

7:30 am Sheraton-McAlpin Hotel Parlor D

H. H. Kellogg, *Chairman*

EMD Uranium

9:00 am Sheraton-McAlpin Hotel Green Room

C. K. McArthur and E. C. Van Blarcom, *Associate Chairmen*

Preparation of High Grade UF_4 by New Methods: *H. G. Petrow and R. J. Allen*, National Lead Co.

Factors in Determining Uranium Concentrate Specifications: *J. R. Nelli, W. C. Manser, and D. S. Arnold*, National Lead Co. of Ohio.

Impact of Yellow Cake Specification on Mill Operation: *W. D. Charles*, National Lead Co., *and N. N. Schiff*, Vitro Rare Metal Co.

Laboratory and Pilot Plant Development of a Copper Ammonia Catalyst for the Dissolution of Uranium in Carbonate Solutions: *M. A. De Sesa, H. E. Gardner, and P. J. Magno*, National Lead Co.

EMD Cobalt

9:00 am Sheraton-McAlpin Hotel Red Room

F. R. Morral and W. M. Fassell, Jr., *Associate Chairmen*

History and Processing of Arsenical Cobalt Silver Ores: *C. R. Whittemore*, Deloro Smelting and Refining Co.

Nickel-Cobalt Separation at Sherritt-Gordon Mines: *V. N. Mackiw, W. C. Lin, T. W. Benz, and R. L. Benoit*, Sherritt-Gordon Mines Ltd.

Production of High-Purity Cobalt Powder: *S. Mellgren*, Amco Research, Inc., *and J. Wulff*, Massachusetts Institute of Technology.

Cobalt in Katanga (film): Union Miniere du Haut-Katanga, Brussels, Belgium.

EMD
Annual Stag Luncheon and Business Meeting

12:15 pm Sheraton-McAlpin Hotel Crystal Room

B. W. Gonser, Division Chairman, *Presiding*

Speaker: Dean C. L. Wilson, University of Missouri

Subject: *Short Cuts*

WEDNESDAY, FEBRUARY 19, PM

EMD Molten Salts

2:00 pm Sheraton-McAlpin Hotel Green Room

Ling Yang and M. A. Steinberg, *Associate Chairmen*

Structural Model for Molten Salts: *J. O'M. Bockris*, University of Pennsylvania.

Constitution of Molten Salts: *G. J. Janz, Rensselaer* Polytechnic Institute.

Some Transport Phenomena in Molten Salts: *R. W. Laity*, Princeton University.

Polarization Phenomena in Electrical Conductivity Measurements of Molten Salts: *D. Argyriades*, Institut für Metallhüttenwesen und Elektrometallurgie, Aachen, Germany.

Activity of Metal Halides in Molten Salt Systems: *Ling Yang and R. G. Hudson*, Carnegie Institute of Technology.

EMD Nickel

2:00 pm Sheraton-McAlpin Hotel Red Room

A. W. Schlechten and C. K. Conard, *Associate Chairmen*

Recovery of High Purity Sulfur, Selenium, and Cobalt in Electrorefining of Nickel: *L. S. Renzoni, R. C. McQuire and W. V. Barker*, International Nickel Co. of Canada Ltd.

Production of High-Grade Iron Ore at Copper Cliff, Ontario: *Paul Queneau, E. H. Bracken, and Daniel Kelly*, International Nickel Co. of Canada Ltd.

Refining of Nickel from the Sudbury Ores (Motion Picture, 50 min): Introduction by *F. F. Wood*, International Nickel Co. Inc.

EMD

Physical Chemistry of Extractive Metallurgy Committee Meeting

3:00 pm Sheraton-McAlpin Hotel Parlor E
C. L. McCabe, *Chairman*

EMD

Titanium, Uranium, and Uncommon Metals Committee Meeting

3:00 pm Sheraton-McAlpin Hotel Parlor D
W. W. Stephens, *Chairman*

THURSDAY, FEBRUARY 20, AM

EMD

Physical Chemistry of Sulfide Systems

9:00 am Sheraton-McAlpin Hotel Green Room
Gerhard Derge and R. E. Lund, *Associate Chairmen*

A Thermodynamic Study of the Titanium-Sulfur System in the Region $TiS_{1.00}$ to $TiS_{1.33}$: *R. P. Abendroth and A. W. Schlechten*, Missouri School of Mines.

Liquid Miscibility Gap in the Quaternary System Fe-Cu-S-C at 1450°C: *D. L. Douglass*, Ohio State University.

A Kinetic Study of the Oxidation of Pyrite in Aqueous Suspension: *D. R. McKay and J. Halpern*, University of British Columbia.

Sulfatization Reactions in the Roasting of Copper Sulfide: *W. H. Porter, J. R. Lewis, and M. E. Wadsworth*, University of Utah.

Mechanism of the PbO, PbS Roast Reaction: *S. J. Merrick and C. S. Samis*, University of British Columbia, *and Ernest Peters*, Electro Metallurgical Co., Div. Union Carbide Corp.

EMD **Aluminum**

9:00 am Sheraton-McAlpin Hotel Red Room
R. F. Cathcart and W. S. Peterson, *Associate Chairmen*

A Preliminary Report on the Structural Phases in Lime-Soda Sinters: *R. V. Lundquist*, U. S. Bureau of Mines.

Procedures for Evaluating Refractories for Aluminum Melting: *H. A. McDonald*, Kaiser Aluminum and Chemical Corp.

Causes and Effects of Metal and Electrolyte Circulation in the Hall Process: *A. F. Johnson*, Consulting Engineer.

Considerations in the Metallurgical Control of an Aluminum Reduction Plant: *A. W. Hook*, Anaconda Aluminum Co.

Rheological Measurements of Mixtures of Coal Tar Pitch With Coke Fines: *Oluf Böckman, Ove Sandberg, and Arne Langrind*, Elektrokemisk, Norway.

EMD-MBD

Solution and Precipitation

9:00 am Statler Hotel Penn Top South
A. Wesner and J. Dasher, *Associate Chairmen*

Resin-in-Pulp Process at Mines Development Inc.: *H. D. Webb, G. F. Richards, and G. T. Bator*, Mines Development Inc.

Climax Uranium Co.'s Approach to Vanadium Recovery by Solvent Extraction: *R. E. Musgrove, E. E. Maurer, and R. E. Fischer*, Climax Uranium Co.

Amine Extraction of Port Radium Leach Liquor: *M. E. Grimes*, Eldorado Mining and Refining Co. Ltd.

New Solvent Extraction Techniques for Uranium Purification: *D. A. Ellis, R. S. Long, and J. E. Magner*, The Dow Chemical Co.

THURSDAY, FEBRUARY 20, PM

EMD-MBD

Symposium: Thickening, Filtration, and Flocculation

2:00 pm Statler Hotel Penn Top South
A. H. Ross and F. T. Davis, *Associate Chairmen*

Panel of Experts

A. A. Wallach, Kaiser Engineers; *W. C. Mason*, Dorr-Oliver, Inc.; *C. Lynn Peterson*, Peterson Filters and Engineering Co.; *W. A. Jordan*, General Mills Inc.; *R. P. Ehrlich*, Rio Tinto Management Services; *B. S. Crocker*, Kilborn Engineering Ltd.; *J. T. Sherman*, U. S. Atomic Energy Commission; *D. A. Dahlstrom*, Eimco Corp.; *E. J. Roberts*, Dorr-Oliver, Inc.; *R. R. Porter*, Consultant; *R. H. Lowe*, American Cyanamid Co.; *R. S. Olson*, Dow Chemical Co.; *N. N. Schiff*, Vitro Rare Metal Co.; *and R. J. Woody*, National Lead Co., Inc.

Summary papers (5 minutes each) by each of the following panel members will be presented to initiate open discussion with all attending invited to participate:

Thickening: *E. J. Roberts and R. J. Woody.*

Filtering: *W. C. Mason, D. A. Dahlstrom, and C. L. Peterson.*

Flocculants: *W. A. Jordan, R. H. Lowe, and R. S. Olson.*

EMD-ISD

Physical Chemistry of Ternary Systems

2:00 pm Sheraton-McAlpin Hotel Green Room
R. Schuhmann, Jr., and K. L. Fetters, *Associate Chairmen*

A Thermodynamic Theorem Pertaining to Univarient Equilibria With Examples From the Systems Fe-Mn-C and Fe-Si-C: *L. S. Darken*, U. S. Steel Corp.

Thermodynamic Measurements in the Fe-Mn-C System: *J. F. Butler and C. L. McCabe*, Carnegie Institute of Technology.

Thermodynamics of the Ti-O-H System: *M. T. Hepworth and R. Schuhmann, Jr.*, Purdue University.

Self and Interdiffusion in Liquid Zinc Amalgams: *H. W. Schadler and R. E. Grace*, Purdue University.

Thermodynamic Properties of the System Pb-S-O Below Fusion Temperatures: *H. H. Kellogg and S. K. Basu*, Columbia University.

Institute of Metals Division

SUNDAY, FEBRUARY 16, PM

IMD

Programs Committee Meeting

4:30 pm Sheraton-McAlpin Hotel Parlor F
R. L. Smith, *Chairman*

MONDAY, FEBRUARY 17, AM

IMD

Diffusion and Imperfections

9:30 am Sheraton-McAlpin Hotel Winter Garden
C. E. Birchenall and R. W. Balluffi, *Associate Chairmen*

A Model for Solute Diffusion in Semiconductors With the Diamond Structure: *R. A. Swalin*, University of Minnesota.

Steady-State Diffusion in Substitutional Solid Solutions: *A. S. Yue*, The Dow Chemical Co., *and A. G. Guy*, Purdue University. (TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME, February 1958)

Effect of Torsional Strains on Self-Diffusion in Silver Single Crystals: *C. H. Lee and Robert Maddin*, University of Pennsylvania.

Atomic Mobility in the Alloy Cu$_3$Au: *W. A. Goering*, Ford Motor Co., and *A. S. Nowick*, Watson Laboratories, International Business Machines Corp.

On the Origin of Dislocations: *Doris Kuhlmann-Wilsdorf*, University of Pennsylvania.

Change in Density of Copper During Creep: *R. C. Boettner and W. D. Robertson*, Yale University.

Quenched-In Vacancies in Noble Metals: *H. Kimura, Robert Maddin, and Doris Kuhlmann-Wilsdorf*, University of Pennsylvania.

Further Observations on the Formation of Intercrystalline Voids During Creep: *C. W. Chen*, Westinghouse Electric Corp.

Intergranular Cavitation in Stressed Copper-Nickel Alloys: *B. J. Reid*, Metal Manufactures Ltd., Port Kembla, Australia, *and J. N. Greenwood*, University of Melbourne, Australia.

Evaporation of Silver Crystals: *J. P. Hirth and G. M. Pound*, Carnegie Institute of Technology.

IMD
Symposium on High-Speed Stressing of Solids—Invited Lectures

9:30 am Sheraton-McAlpin Hotel Ballroom
Bruce Chalmers, *Chairman*

Rapid Initiation of Yielding in Body-Centered-Cubic Metals: *D. S. Wood*, California Institute of Technology.

Effects of Detonation Waves in Metals: *J. S. Rinehart*, Smithsonian Astrophysical Observatory.

Behavior of Mono and Polycrystalline Metals in the 20 to 100 Microsecond Regime: *R. M. Davies*, University College, Aberyswyth, Wales.

MONDAY, FEBRUARY 17, PM

IMD
Shaping and Forming Committee

2:00 pm Sheraton-McAlpin Hotel Parlor D
E. S. Rowland, *Chairman*

IMD
Symposium on High-Speed Stressing of Solids—Contributed Papers

2:30 pm Sheraton-McAlpin Hotel Ballroom
J. C. Fisher and K. A. Jackson, *Associate Chairmen*

Use of an Explosive Press for Impulsive Loading Studies: *E. W. LaRocca and John Pearson*, U. S. Naval Ordnance Test Station.

High-Speed Motion of Dislocations in LiF Crystals: *J. J. Gilman and W. G. Johnston*, General Electric Co.

Explosive Deformation of Low-Carbon Steel: *Samuel Katz and D. R. Curran*, Stanford Research Institute.

Effect of Carbon and Manganese Content on High-Speed Flow Properties of Mild Steel: *A. M. Sullivan and J. M. Krafft*, U. S. Naval Research Laboratory.

Microstructure of Metals Subjected to Intensive Plane Shock Waves: *Cyril S. Smith*, University of Chicago.

Fracture of Aluminum Under Explosive Loads: *R. S. Davis*, Harvard University.

Results of Some Impact Experiments: *Enrico Volterra*, University of Texas.

Explosive-Induced Fracture: *J. J. Kelly*, Stanford Research Institute.

Roll Compacting of Pure Nickel Strip From Powder: *J. A. Lund*, University of Columbia.

IMD
Deformation

2:30 pm Sheraton-McAlpin Hotel Winter Garden
W. C. Ellis and F. D. Rosi, *Associate Chairmen*

On the Strain-Hardening of Aluminum Single and Bicrystals: *R. S. Davis and U. F. Kocks*, Harvard University.

Creep Characteristics of Magnesium Single Crystals in the Temperature Range of 78° to 364°K: *Hans Conrad*, Westinghouse Electric Corp., *and W. D. Robertson*, Yale University.

An Investigation of the Rate-Controlling Mechanism for Plastic Flow of Copper Crystals at 90° and 170°K: *Hans Conrad*, Westinghouse Electric Corp.

Deformation of Aluminum Single Crystals in Shear: *W. L. Phillips, Jr., and W. D. Robertson*, Yale University.

Dislocation Structure of Slip Bands in Iron: *J. R. Low, Jr. and R. W. Guard*, General Electric Co.

Slip Line Measurements on Alpha-Brass Single Crystals: *J. T. Fourie*, National Physical Laboratory, Pretoria, South Africa, and *H. G. F. Wilsdorf*, Franklin Institute.

Room-Temperature Deformation Processes in Zirconium: *E. J. Rapperport*, Nuclear Metals, Inc.

Temperature Dependence of the Flow Stress in Age-Hardened Al-4 Pct Cu Single Crystals: *A. Kelly and C. Chiou*, Northwestern University.

Creation of Cleavage Steps by Dislocations: *J. J. Gilman*, General Electric Co.

Yielding in Zinc Single Crystals: *Norman Brown*, University of Pennsylvania.

IMD
Publications Committee Meeting

3:30 pm Sheraton-McAlpin Hotel Parlor E
Robert Maddin, *Chairman*

IMD
Membership Committee Meeting

4:30 pm Sheraton-McAlpin Hotel Parlor D
J. H. Keeler, *Chairman*

TUESDAY, FEBRUARY 18, AM

IMD
Chemistry and Physics of Metals Committee Breakfast Meeting

7:30 am Sheraton-McAlpin Hotel Parlor D
J. C. Fisher, *Chairman*

IMD
Mechanical Properties

9:00 am Sheraton-McAlpin Hotel Crystal Room
Norman Brown and J. W. Frederickson, *Associate Chairmen*

Effect of Copper, Nickel, Iron, and Chromium on the Tensile Properties of Preferentially Oriented Beryllium Sheet: *F. M. Yans and A. R. Kaufmann*, Nuclear Metals, Inc., *and A. D. Donaldson*, Atomics International.

Effect of Composition and Heat Treatment on the Uniform Elongation and Flow Properties of Alpha-Beta Titanium Alloys: *A. J. Griest, H. A. Robinson, and P. D. Frost*, Battelle Memorial Institute. (TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME, February 1958).

Some Mechanical Properties of Zone-Refined Titanium in the Temperature Range From 298° to 4.2°K: *J. L. Rutherford, M. Herman, and R. L. Smith*, Franklin Institute.

Observation of a Transition-Point in the Plastic Deformation of Polycrystalline Iron: *J. C. Wijman*, The Dow Chemical Co., *and M. Gensamer*, Columbia University.

Effect of Hot Working on the Structure and Creep-Rupture Properties of Heat-Resistant Alloys: *A. P. Coldren and J. W. Freeman*, University of Michigan, *and C. B. Hartley*, Wright Air Development Center.

Preparation and Properties of Europium: *F. H. Spedding, J. J. Hanak, and A. H. Daane*, U. S. Atomic Energy Commission, Iowa State College.

IMD
Structural Properties of Metals and Alloys (I)

9:00 am Sheraton-McAlpin Hotel Colonial Room

Harold Margolin and L. S. Castleman, *Associate Chairmen*

Eutectic Solidification Structures: *H. W. Weart*, Westinghouse Electric Corp., *and D. J. Mack*, University of Wisconsin.

Grain Boundary Migration in High-Purity Lead Crystals: *K. T. Aust and J. W. Rutter*, General Electric Co.

Effect of Orientation on Strain-Induced Grain Boundary Migration in Silicon-Iron Bicrystals: *K. T. Aust, E. F. Koch, and C. G. Dunn*, General Electric Co.

Cellular Substructure in Zinc Single Crystals Grown From the Melt: *V. V. Damiano and M. Herman*, Franklin Institute.

Effects of the Proeutectoid Ferrite Reaction on the Formation of Pearlite: *H. I. Aaronson*, Carnegie Institute of Technology.

Solubility and Precipitation of Vanadium Nitride in Alpha and Gamma Iron: *R. W. Fountain*, Electro Metallurgical Co., Div. Union Carbide Corp., *and John Chipman*, Massachusetts Institute of Technology.

Mechanism of Age Hardening in Magnesium-Zinc Alloys: *L. Sturkey and J. B. Clark*, The Dow Chemical Co.

Precipitation Processes in Copper-Rich Copper-Iron Alloys: *Alvin Boltax*, Nuclear Metals Inc.

IMD
Executive Committee Luncheon Meeting

12:15 pm Sheraton-McAlpin Hotel Parlor F

W. R. Hibbard, Jr., *Chairman*

IMD
Committee on Electrical and Magnetic Metals Luncheon Meeting

12:15 pm Sheraton-McAlpin Hotel Parlor A

J. J. Becker, *Chairman*

WEDNESDAY, FEBRUARY 19, AM

IMD
Structural Properties of Metals and Alloys (II)

9:00 am Sheraton-McAlpin Hotel Ballroom

G. M. Pound and C. G. Dunn, *Associate Chairmen*

Metallographic Observation of Rare Earth Metals: *C. G. Kirkpatrick and V. F. Novy*, Research Chemicals, Inc.

X-Ray Analysis of Deformed Germanium, Gallium Antimonide, and Indium Antimonide: *C. Kolm, E. P. Warekois, and S. A. Kulin*, Lincoln Laboratory, Massachusetts Institute of Technology.

Selective Revealing of Screw Component Dislocations by Low-Energy Cathodic Sputtering: *B. Meckel and R. A. Swalin*, University of Minnesota.

Some Observations on the Recrystallization of a Silicon-Iron Crystal: *Hsun Hu*, Westinghouse Electric Corp.

Theoretical Interpretation of Metallurgical Effects Produced by Vibrational Treatments: *M. C. Huffstutler, Jr.*, Texas Western College.

Redistribution of a Second Phase During Annealing in a Temperature Gradient: *Paul Shewmon*, Westinghouse Electric Corp.

IMD
General Metallurgy (I)

9:00 am Sheraton-McAlpin Hotel Winter Garden

O. T. Marzke and J. J. Harwood, *Associate Chairmen*

Determination of Tests for Hydrogen Embrittlement of Titanium Alloys: *R. R. Kennedy*, Crane Co.

Solute Gradient Melting: *J. M. Lommel*, General Electric Co., *and Bruce Chalmers*, Harvard University.

Solid Solubilities of Iron and Nickel in Beryllium: *S. H. Gelles*, Nuclear Metals Inc., *R. E. Ogilvie*, Massachusetts Institute of Technology, *and A. R. Kaufmann*, Nuclear Metals, Inc.

Nickel-Titanium-Carbon System: *E. R. Stover*, General Electric Co., *and J. Wulff*, Massachusetts Institute of Technology.

Silver-Zirconium System: *J. O. Betterton, Jr., and D. S. Easton*, Oak Ridge National Laboratory.

Equilibrium Diagram of Indium-Zirconium in the Region 0 to 26 Atomic Pct In: *J. O. Betterton, Jr., and W. K. Noyce*, Oak Ridge National Laboratory.

Antimony-Zirconium System in the Range 0 to 5 Atomic Pct Sb: *J. O. Betterton, Jr., and W. M. Spicer*, Oak Ridge National Laboratory.

IMD
Annual Business Meeting

10:45 am Sheraton-McAlpin Hotel Ballroom

W. R. Hibbard, Jr., *Chairman*

IMD
Annual Lecture

11:00 am Sheraton-McAlpin Hotel Ballroom

Grover J. Holt and W. R. Hibbard, Jr., *Associate Chairmen*

Speaker: *A. H. Cottrell*, Atomic Energy Research Establishment, Harwell, England.

Subject: *Theory of Brittle Fracture in Metals*

IMD
Titanium Committee Luncheon Meeting

12:15 pm Sheraton-McAlpin Hotel Parlor F

L. S. Busch, *Chairman*

WEDNESDAY, FEBRUARY 19, PM

IMD-ISD
Russian Metallurgical Technology

2:00 pm Sheraton-McAlpin Hotel Ballroom

David Swan and J. P. Nielsen, *Associate Chairmen*

Metallurgical Education and Supply of Metallurgists in USSR: *John Chipman and Morris Cohen*, Massachusetts Institute of Technology.

Metallurgical Research in USSR: *J. H. Hollomon and W. R. Hibbard, Jr.*, General Electric Co.

Application of Research in USSR: *T. W. Lippert*, Titanium Metals Corp. of America.

Status of Industrial Technology in the Iron and Steel Industry: *D. J. Carney*, U. S. Steel Corp.

THURSDAY, FEBRUARY 20, AM

IMD
General Metallurgy (II)

9:00 am Sheraton-McAlpin Hotel Winter Garden

F. H. Wilson and D. E. Trout, *Associate Chairmen*

Commercial Techniques for Obtaining Sound Titanium Castings: *M. L. Torti*, National Research Corp.

Effect of the Order-Disorder Reaction on the Magnetic Anisotropy and Magnetostriction of Single Crystals of the Ferromagnetic Aluminum Iron Alloys: *R. C. Hall*, Westinghouse Electric Corp.

A Note on the Use of Aluminum for the Deoxidation of Palladium and Its Alloys: *R. N. Rhoda and R. H. Atkinson*, International Nickel Co. (TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME, February 1958).

Comparison of Arc Melting Conditions and Their Effects on Reactor-Grade Zirconium Alloy Ingots: *J. H. Hart*, Westinghouse Electric Corp.

Metallurgical Factors Affecting the Corrosion of Uranium-Base Alloys in High-Temperature Water: *M. W. Burkart, R. D. Leggett, and R. A. Wolfe*, Westinghouse Electric Corp.

Use of Plastecene to Simulate Metal Flow in Tandem Extrusion: *E. J. Rapperport and W. B. Nowak*, Nuclear Metals Inc.

Motion Pictures of Interface Flow in Tandem Extrusions of Plastecene: *W. B. Nowak and E. J. Rapperport*, Nuclear Metals Inc.

A Systematic Investigation of Metal Tandem Extrusions: *W. B. Nowak and E. J. Rapperport*, Nuclear Metals Inc., *and W. Wegner*, U. S. Navy.

Temperature Dependence of the Free Energy Difference Between Body-Centered-Cubic and Face-Centered-Cubic Iron: *Larry Kaufman*, Lincoln Laboratory, Massachusetts Institute of Technology.

Effect of Plastic Deformation on the Resistivity of Cu-Pd Alloys: *Erik Klockholm and Barry Hyatt*, Franklin Institute.

Electron Probe Micro-Analysis of Sub-Micron Precipitates in Alloy Steels: *R. M. Fisher*, Edgar C. Bain Laboratory, U. S. Steel Corp.

IMD
Processing of High-Temperature Alloys

9:00 am Sheraton-McAlpin Hotel Ballroom

N. J. Grant and M. Achter, *Associate Chairmen*

Historical Review of Melting and Casting of High-Temperature Alloys: *F. S. Badger*, Haynes Stellite Co., Div. Union Carbide Corp.

Effects of Variations in Nitrogen and Manganese Content on the Structure and High-Temperature Properties of Cast X-40 Alloy: *E. E. Fletcher and A. R. Elsea*, Battelle Memorial Institute.

Application of Vacuum Melting to Investment Casting: *J. A. Miller*, Haynes Stellite Co., Div. Union Carbide Corp.

Effects of Certain Processing Variables on Physical Properties of Several High-Temperature Alloys: *P. E. Hamilton, E. L. Bolin, and R. E. Roth*, Allison Div., General Motors Corp.

Fabrication of High-Temperature Materials by Slip Casting: *L. M. Schifferli, Jr.*, Haynes Stellite Co., Div. Union Carbide Corp.

Mechanism of Beneficial Effects of Boron and Zirconium on Creep-Rupture Properties of a Complex Heat-Resistant Alloy: *R. F. Decker and J. W. Freeman*, University of Michigan.

THURSDAY, FEBRUARY 20, PM

IMD
Wrought Alloys

2:00 pm Sheraton-McAlpin Hotel Ballroom

G. V. Smith and F. N. Darmara, *Associate Chairmen*

Relationship of High-Temperature Properties to Working Procedure: *J. W. Freeman*, University of Michigan.

Cold-Rolling Enhances Mechanical Properties: *D. W. Schulz*, Haynes Stellite Co., Div. Union Carbide Corp.

Effect of Processing Variables on the Properties of Udimet 500: *E. J. Vargo and G. J. Guarnieri*, Thompson Products Inc.

Effect of Processing Variables on the Properties of M252: *J. Luchok and R. Stuligross*, General Electric Co., *and D. S. Chambers*, Vanadium-Alloys Steel Co.

Statistical Evaluation of the Properties Obtained From Air and Vacuum Arc Melted W-545 Alloy: *J. Bulina and J. T. Brown*, Westinghouse Electric Corp.

Effect of Rhenium on Fabrication and Ductility of Molybdenum: *R. I. Jaffee and C. T. Sims*, Battelle Memorial Institute.

IMD
Physical Metallurgy of Cobalt

2:00 pm Sheraton-McAlpin Hotel Winter Garden

F. R. Morral and G. A. Fritzlen, *Associate Chairmen*

Development of Cobalt-Base Alloys: *J. B. McAndrew, J. J. Rausch, and D. W. Levinson*, Armour Research Foundation.

Damping and Shear Modulus of Cobalt: *R. E. Maringer and L. L. Marsh*, Battelle Memorial Institute.

Properties of Zone-Refined and of Powder-Metallurgy Cobalt: *F. R. Morral, C. T. Sims, and E. F. Adkins*, Battelle Memorial Institute.

Influence of Cobalt on the Transformation of a Chromium-Alloyed Austenite: *P. Nicolaides, D. Coutsouradis, and L. Habraken*, Centre National de Recherches Metallurgiques, Belgium.

Precipitation Phenomena in Cobalt-Tantalum Alloys: *M. Korchynsky and R. W. Fountain*, Electro Metallurgical Co., Div. Union Carbide Corp.

Nonmetallic Dispersions in Cobalt: *E. F. Adkins, C. T. Sims, and R. I. Jaffee*, Battelle Memorial Institute.

Exploration of the Electrical Resistivity of Cobalt-Base Alloys: *J. C. Stewart, J. G. Dunleavy, and A. M. Hall*, Battelle Memorial Institute.

Phase Transformations in Titanium-Rich Alloys of Titanium and Cobalt: *P. R. Swann and J. G. Parr*, University of Alberta.

Comparison of the Mechanical Properties and Oxidation Resistance of Two Nickel- and Two Cobalt-Base Heat-Resisting Alloys Melted in Vacuum and in Air or Argon: *M. J. Stutzman and J. W. Cunningham*, Westinghouse Electric Corp.

Some Portions of the Quaternary System Fe-Cr-C-Co: *P. Nicolaides, D. Coutsouradis, and L. Habraken*, Centre National de Recherches Metallurgiques, Belgium.

Iron and Steel Division

MONDAY, FEBRUARY 17, AM

ISD
Slags and Slag-Metal Reactions

9:30 am Sheraton-McAlpin Hotel Colonial Room

W. O. Philbrook and F. C. Langenberg, *Associate Chairmen*

Activity Coefficients of MnO and $(FeO)_1$ in $CaO\text{-}SiO_2\text{-}(FeO)_1$ Slags $CaO\text{-}SiO_2\text{-}(FeO)_1$: *H. L. Bishop, Jr.*, Allegheny Ludlum Steel Corp., *N. J. Grant, and John Chipman*, Massachusetts Institute of Technology.

Electrochemical Characteristics of $FeO\text{-}MnO\text{-}SiO_2$ Melts: *D. A. Dukelow*, Jones & Laughlin Steel Corp., *and Gerhard Derge*, Carnegie Institute of Technology.

Rate and Mechanism of the Desulfurization of Carbon-Saturated Iron: *L. D. Kirkbride and Gerhard Derge*, Carnegie Institute of Technology.

Effect of Convection on the Reaction $C + FeO = CO + Fe$: *J. C. Campbell*, Dominion Steel and Coal Corp., *and T. B. King*, Massachusetts Institute of Technology.

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MONDAY, FEBRUARY 17, PM

ISD

Physical Chemistry of Liquid Iron Solutions

2:30 pm Sheraton-McAlpin Hotel Colonial Room

N. A. Parlee and F. W. Luerssen, *Associate Chairmen*

Activities of Fe and Ni in Liquid Iron-Nickel Solutions: *Rudolph Speiser, A. J. Jacobs, and J. W. Spretnak*, Ohio State University.

Activities in Liquid Iron-Nickel Alloys: *G. R. Zellars and J. P. Morris*, U. S. Bureau of Mines.

Activity of Oxygen in Liquid Iron Alloys: *T. P. Floridis*, General Electric Co., *and John Chipman*, Massachusetts Institute of Technology.

Solubility and Activity of Titanium in Carbon-Saturated Iron: *F. D. Delve*, Jones & Laughlin Steel Corp.

TUESDAY, FEBRUARY 18, AM

ISD

Cerium in Steels and Steelmaking

9:00 am Sheraton-McAlpin Hotel Ballroom

J. C. Fulton and E. R. Morgan, *Associate Chairmen*

Equilibrium Between Cerium and Sulfur in Liquid Iron: *F. C. Langenberg*, Crucible Steel Co. of America, *and John Chipman*, Massachusetts Institute of Technology.

Determination of the Cerium Habit in Carbon Steel: *R. H. Singleton*, Allison Div., General Motors Corp.

ISD

Howe Memorial Lecture

11:00 am Sheraton-McAlpin Hotel Ballroom

Augustus B. Kinzel and H. B. Emerick, Associate Chairmen

Speaker: *Maxwell Gensamer*, Columbia University

Subject: *The Structure of Metals and the Strength of Structures*

ISD

Stag Luncheon and Business Meeting

12:15 pm Sheraton-McAlpin Hotel Winter Garden

H. B. Emerick, *Chairman*

Speaker: Tom C. Campbell, Editor-in-Chief, THE IRON AGE

Subject: *What's Ahead for the Steel Industry in 1958-59?*

WEDNESDAY, FEBRUARY 19, AM

ISD

Executive Committee Breakfast Meeting

7:30 am Sheraton-McAlpin Hotel Parlor E

H. B. Emerick, *Chairman*

Behavior of Metallurgical Systems

9:00 am Sheraton-McAlpin Hotel Colonial Room

T. B. King and T. B. Winkler, *Associate Chairmen*

Surface Tension and Contact Angles in Some Liquid Metal-Solid Ceramic Systems at Elevated Temperatures: *B. C. Allen and W. D. Kingery*, Massachusetts Institute of Technology.

Air Melting of Iron-Aluminum Alloys: *V. F. Zackay and W. A. Goering*, Ford Motor Co.

Oxygen-Lime Injection—A New Steelmaking Process: *B. Trentini and M. Allard*, Institut de Recherches de la Sidérurgie, St. Germain-en-Laye, France.

ISD

Physical Chemistry of Steelmaking Committee Luncheon Meeting

12:15 pm Sheraton-McAlpin Hotel Parlor D

B. R. Queneau, *Chairman*

WEDNESDAY, FEBRUARY 19, PM

ISD

Technology of Iron and Steelmaking Processes

2:00 pm Sheraton-McAlpin Hotel Colonial Room

J. F. Elliott and C. R. Taylor, *Associate Chairmen*

Vacuum Casting of Large Forging Ingots: *J. N. Hornak and M. A. Orehoski*, U. S. Steel Corp.

An Investigation of Gas Flow in a Small Blast Furnace: *H. W. Hosking*, The Broken Hill Proprietary Co. Ltd., Shortland, Australia, *W. O. Philbrook*, Carnegie Institute of Technology, *and N. B. Melcher*, U. S. Bureau of Mines.

Experimental Blast Furnace as a Research Facility: *N. B. Melcher and M. W. Royer*, U. S. Bureau of Mines.

Gas Flow in an Open Hearth Model: *R. H. Jones and D. F. Brion*, Bethlehem Steel Co.

ISD-IMD

Russian Metallurgical Technology

2:00 pm Sheraton-McAlpin Hotel Ballroom

David Swan and J. P. Nielsen, *Associate Chairmen*

Metallurgical Education and Supply of Metallurgists in USSR: *John Chipman and Morris Cohen*, Massachusetts Institute of Technology.

Metallurgical Research in USSR: *J. H. Hollomon and W. R. Hibbard, Jr.*, General Electric Co.

Application of Research in USSR: *T. W. Lippert*, Titanium Metals Corp. of America.

Status of Industrial Technology in the Iron and Steel Industry: *D. J. Carney*, U. S. Steel Corp.

ISD

Mechanical Working Committee Meeting

5:00 pm Sheraton-McAlpin Hotel Parlor D

E. L. Robinson, *Chairman*

THURSDAY, FEBRUARY 20, AM

ISD-MBD

Pyrolysis and Agglomeration

9:00 am Statler Hotel Sky Top

F. D. DeVaney and R. L. Stephenson, *Associate Chairmen*

FluoSolids Roasting of Sulfides for Recovery of Copper, Iron, and Sulfur: *H. Kurushima*, Dowa Mining Co., Tokyo, Japan, *and R. M. Foley*, Dorr-Oliver, Inc.

Beneficiation of Low-Grade Iron Ores Involving Direct Reduction: *Alex Stewart*, National Lead Co., *and H. K. Work*, New York University.

Recovery of Iron Ores Containing Titanium, Manganese, Chromium, and Alkali Metal Sulfates: *A. G. Oppegaard, O. Moklebust, and G. G. Reed, Jr.*, National Lead Co.

Reduction of High-Grade Port Henry Magnetite Concentrates: *D. E. Babcock and E. C. Smith*, Republic Steel Corp.

Beneficiation of Iron Ores High in Phosphorus and Sulfur: *Alex Stewart and G. G. Reed, Jr.*, National Lead Co., *and P. Herasymenko*, New York University.

ISD-EMD

Physical Chemistry of Ternary Systems

2:00 pm Sheraton-McAlpin Hotel Green Room

R. Schuhmann, Jr., and K. L. Fetters, *Associate Chairmen*

A Thermodynamic Theorem Pertaining to Univarient Equilibria With Examples From the Systems Fe-Mn-C and Fe-Si-C: *L. S. Darken*, U. S. Steel Corp.

Thermodynamic Measurements in the Fe-Mn-C System: *J. F. Butler and C. L. McCabe*, Carnegie Institute of Technology.

Thermodynamics of the Ti-O-H System: *M. T. Hepworth and R. Schuhmann, Jr.*, Purdue University.

Self and Interdiffusion in Liquid Zinc Amalgams: *H. W. Schadler and R. E. Grace*, Purdue University.

Thermodynamic Properties of the System Pb-S-O Below Fusion Temperatures: *H. H. Kellogg and S. K. Basu*, Columbia University.

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COMING EVENTS

Jan. 10, AIME St. Louis Section, joint meeting with AIChE St. Louis Section, Hotel York, St. Louis.

Jan. 15, AIME New York Section, Physical Metallurgy Group, plant trip to Federal Telecommunication Laboratories, Nutley, N. J.

Jan. 16, AIME Cleveland Section, annual meeting and ladies night; speaker: J. W. Robb; subject: *Curious Patents;* Carter Hotel, Cleveland.

Jan. 16, AIME Utah Section, panel discussion: *Industrial Engineering Practices in the Mineral Industries;* moderator: I. K. Hearn, Salt Lake City.

Jan. 22, AIME Niagara Frontier Section, election of officers, Red Coach Inn, Niagara Falls, N. Y.

Jan. 28, AIME Connecticut Section, Bridgeport meeting, University Club, Bridgeport, Conn.

Feb. 12, AIME San Francisco Section, joint meeting with local section, Canadian Institute of Mining and Metallurgical Engineers, Royal Connaught Hotel, Hamilton, Ontario.

Feb. 13, AIME Cleveland Section, Carter Hotel, Cleveland.

Feb. 16-20, AIME Annual Meeting, Statler and Sheraton-McAlpin Hotels, New York.

Mar. 12, AIME New York Section, Powder Metallurgy Group, Brass Rail Restaurant, New York.

Mar. 17-21, EJC Nuclear Congress, International Amphitheatre, Chicago.

Mar. 20, AIME Cleveland Section, regional symposium, Carter Hotel, Cleveland.

Mar. 27-28, AIME San Francisco Section, St. Francis Hotel, San Francisco.

Apr. 14-16, AIME, 41st National Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Conference, Hotel Statler, Cleveland.

April 23, AIME Niagara Frontier Section, joint meeting with local section, Canadian Institute of Mining and Metallurgical Engineers, Royal Connaught Hotel, Hamilton, Ontario.

May 5-6, AIME, Conference on Properties of High-Strength Steel, Penn-Sheraton Hotel, Pittsburgh.

May 5, 6, AIME High-Temperature Materials Conference, Ambassador Hotel, Los Angeles.

May 12-16, Southwestern Metal Exposition and Congress, State Fair Park, Dallas.

May 27-29, AIME Third Reactive Metals Conference; host section: Niagara Frontier Section; Statler Hotel, Buffalo.

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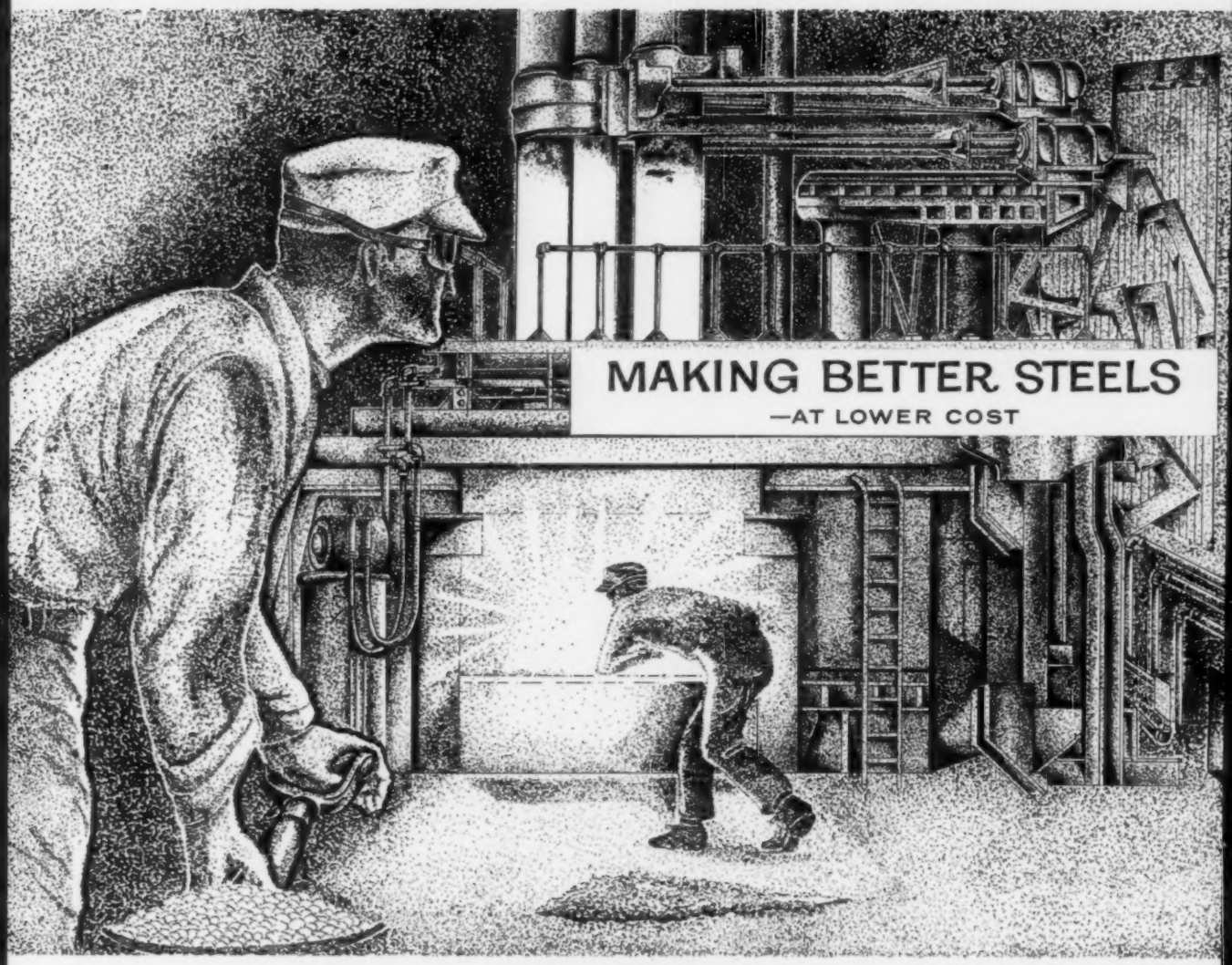

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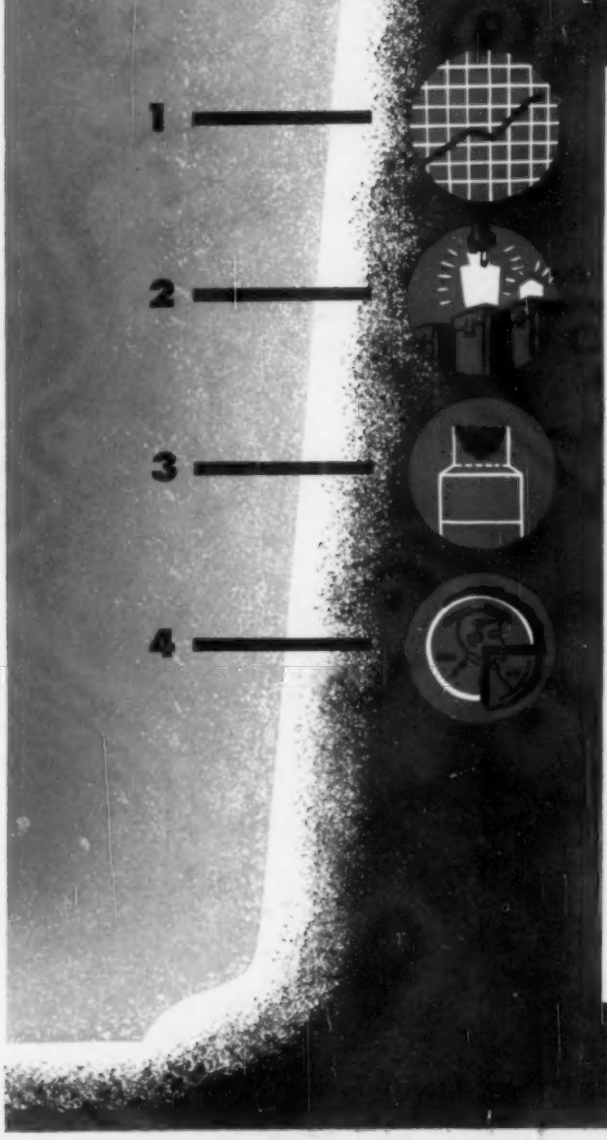

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